CT-EMFAC: A COMPUTER MODEL TO ESTIMATE TRANSPORTATION PROJECT EMISSIONS

UC Davis-Caltrans Air Quality Project
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A request to create a transportation project-level emissions analysis tool based on the California Air Resources Board EMFAC2007 emissions model.

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1. INTRODUCTION

1.1 About CT-EMFAC

The new California-specific project-level analysis tool, CT-EMFAC, is designed to model criteria pollutants, Mobile Source Air Toxics (MSATs) and carbon dioxide using the latest version of the California Mobile Source Emission Inventory and Emission Factors model, EMFAC2007. This new tool replaces an older model (also called CT-EMFAC) developed at Caltrans in the early 1990's; the old version was based on the now-outdated EMFAC7F emissions model, and lacked many of the capabilities included in the new tool. Compared to the old CT-EMFAC, the new tool expands the range of pollutants available for analysis. In addition to providing default or user-defined composite emission factors, the new tool can also calculate project-level emissions based on user-specified vehicle miles traveled-speed distributions.

Specifically, this tool calculates emission factors and project-level emissions inventories for the following pollutants:

- Six primary criteria pollutants– Total Organic Gases (TOG), Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Oxides of Sulfur (SOx), Particulate Matter 10 microns or less in diameter (PM10), and Particulate Matter 2.5 microns or less in diameter (PM2.5);
- One greenhouse gas – Carbon Dioxide (CO2); and
- Six MSATs– Diesel PM, Formaldehyde, Acetaldehyde, Benzene, 1,3-Butadiene, and Acrolein.

The types of emission processes modeled in this tool are:

- Running exhaust– pollutants emitted from the vehicle tailpipe while it is traveling; and
- Running losses– evaporative TOG emissions that occur when hot fuel vapors escape from the fuel system or overwhelm the carbon canister while the vehicle is operating.

The new version of CT-EMFAC also has the capability to calculate idling emissions – tailpipe emissions that occur while the vehicle is operating but not traveling. However, given that EMFAC2007 only provides idling emission factors for heavy-duty trucks, idling emission factors and emissions are currently not reported in CT-EMFAC output.

This tool can be used to estimate project-level emissions for various regulatory requirements. For example, the tool can quantify emissions effects of Transportation Control Measures (TCMs), and evaluate build vs. no-build project alternatives for National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) assessments. CT-EMFAC can also be used to complete federally mandated CO and PM transportation conformity project assessments in CO and PM air quality nonattainment areas. In addition, CT-EMFAC can be used to meet U.S. Federal Highway Administration (FHWA) guidance to estimate project-level MSAT emissions impacts. The tool is also a planning resource; it enables project analysts to test the sensitivity of emissions to various transportation activity scenarios.

1.2 About This Documentation

This document is aimed at familiarizing new users to the CT-EMFAC tool. Section 2 introduces the system requirements for running the software, describes installation and removal processes, and provides a quick-start guide to use the software. CT-EMFAC is "user-friendly;" most experienced project-level analysts will be able to operate the tool after reading Section 2. Section 3 details the data entry steps to run the model; the section focuses on generating composite emission factors and calculating emissions. This section also explains the information contained in the model output files. Section 3 is oriented towards novice users with little experience in project-level emissions analysis. The appendixes include more detailed information about the software's development.

2. GETTING STARTED

2.1 Installation

2.1.1 System Requirements

CT-EMFAC requires a PC running Windows 95 or later, such as Windows XP or Windows Vista. The installation requires at least 600 MB of free disk space on the destination drive. At least 128 MB of RAM is required for running the program. Calculations may be extremely slow on a system with less than 128 MB of RAM.

2.1.2 What's on the installation CD

CT-EMFAC is delivered using an installation CD. There are two folders (i.e., *dotnetframe* and *CT-EMFAC*), a copy of this documentation, and a *ReadMe.txt* file on the CD.

(1) *dotnetframe* contains a file *'dotnetfx.exe'* for the installation of Microsoft .Net Framework.

(2) *CT-EMFAC* includes two subfolders and one *.exe* file:

- subfolder *'alldatabase'* includes an 500MB ACCESS database file, storing the detailed emission factors created using EMFAC 2007,
- subfolder *'output'* includes two example output files for Sacramento County (emission factor and emission calculation files), and
- file *'CT-EMFAC.exe'* is the software execution to open the Graphical User Interface (GUI).

(3) *ReadMe.txt* is a short description of installation and operating instructions used for quick reference.

2.1.3 How to install CT-EMFAC

To install and open CT-EMFAC on your computer, follow these steps:

Step 1: Copy all folders and files in the CD to your computer's hard-drive;

Step 2: [Only complete this step if you are not sure whether or not your work site has installed Microsoft .Net Framework.] After copying, open the *'dotnetframe'* folder on your hard-drive, then double click on file 'dotnetfx.exe' and follow the instructions to install Microsoft .Net Framework;

Step 3: Go to the *'CT-EMFAC'* folder, double-click file *'CT-EMFAC.exe'* to open the interface; and

Step 4: You can also create a shortcut of *'CT-EMFAC.exe'* and copy it to your desktop.

2.1.4 How to remove CT-EMFAC

Since this program does not come with an installer, users do not need to use the Windows “Add/Remove Programs” option on the Control Panel to remove the program. You can simply remove the program by directly deleting all of the files associated with the program.

2.2 CT-EMFAC Quick Start

Once CT-EMFAC starts, you will see a title page and two worksheet tabs: “Emission Factors” and “Emission Calculations.” From the title page, you can navigate to either one of these two pages. The Emission Factors page is used to generate project-specific composite emissions factors, and the Emission Calculations page is used to calculate project-specific emissions based on the output from the Emission Factors page.

2.2.1 Emission Factor Page

The Emissions Factors page allows the user to create an analysis scenario for a specific air basin, county, or statewide application. The user selects an analysis year, the season of interest, and then determines whether to use an EMFAC2007 default fleet, or whether to specify the percentage of trucks compared to other vehicles. In this tool, all medium-duty and above trucks (gasoline- and diesel-powered) are assigned to the “Truck” category[1]. The software then uses EMFAC2007 data to assign vehicles to their appropriate technology classes and fuel type. The user can also select the pollutants of interest, and run the model to generate emission factors. The resulting file (which has a filename extension of *“*.ef”* to identify it as an emission factor file) is available for immediate or future analysis use.

The following are step-by-step instructions to specify parameters on this page:

- **Scenario Title**: create a title for the run; CT-EMFAC will use it for the output file name, and then automatically save the respective output file in the *'output'* folder.

[1] This approach, developed in consultation with CARB, Caltrans, and FHWA staff, provides consistency with field practices used by project analysts charged with estimating truck vs. light-duty vehicle travel activity. Appendix A includes further detail on the model development methodology.

- **Geographic Area**: select one of the three area types; if either 'Air Basin' or 'County' is selected, you also need to choose one specific air basin or county from the drop-down list on the right.
- **Analysis Year**: select a target calendar year from the drop-down list.
- **Season**: select one of the three season types.
- **Vehicle Mix**: you can choose 'Use Default' to apply the default fleet mix values; alternatively, if you have project-specific vehicle mix data, select 'Input Percentage' and then input percentages for trucks and others (e.g., 10 for trucks and 90 for others; the total must be 100%).
- **Pollutants**: select pollutants to be calculated.
- **Toxics Speciation**: select 'CARB Factors' (the other option, 'EPA Factors', is unavailable in this version).
- Click '**RUN**' at the bottom to start the calculation; you will see a pop-up message saying 'This process may take up to several minutes, depending on the speed of your computer'; click 'OK' to continue. (Note that CT-EMFAC will start to query emission factors from the database, so it may take several minutes to finish the run. If your computer has relatively low-speed CPU and smaller RAM, the running time could be longer.)
- After the scenario run is done, the output file *'scenario title.ef'* can be found in the *'output'* folder.
- Click '**RESET**' and input new parameters if a new scenario run for this 'Emission Factors' tab is needed.
- Click '**NEXT**' if you need to calculate total project emissions using the 'Emission Calculations' tab. (Note that you have to click 'Run' to obtain emission factors first before you proceed to click 'Next'.)

2.2.2 Emission Calculations Page

Users select which emissions factors to use, either from the current or a saved emission factor run, and then input the travel activities appropriate for their project. Users have several options to input travel activity. Once the model is run, the resulting file is given a *"*.ec"* filename extension to identify it as an emissions calculations output file.

The following are step-by-step instructions to specify parameters on this page:

- **Scenario Title**: create a title (it can be the same or different from the title for the 'Emission Factors' tab run); CT-EMFAC will use the title as the output file name, and save the respective output file in the 'output' folder.
- **Emission Factors**: select 'Current' to use the most recent 'Emission Factors' output; or select 'Choose From a Saved Scenario' and use the browse window on the right to find the target 'Emission Factors' output file in any folder. Please note: if a user

chooses 'current', the emissions inventory output file will automatically appear in the default 'output' folder. However, if a user chooses 'From a Saved Scenario', the output file will appear in the same folder where the saved scenario is located.)

- **Travel Activities**: select 'VMT' or 'Volume and Road Length', depending on the data available. Then input the data (total VMT, VMT distribution by speed bin, and average vehicle idling time) into respective boxes for 'Peak' or 'Off Peak' or both. The user does not need to input anything if the values are zeros; simply leave the textboxes blank.
- **Pollutants**: the pollutants included in the chosen 'Emission Factors' file will be automatically checked on this page. Users need to do nothing in this step.
- Click '**RUN**' at the bottom to start the calculation; the scenario run should be done promptly.
- After the scenario run is completed, the output file *'scenario title.ec'* can be found in the 'output' folder.

Notes:

- Output format: The legibility and organization of the output file varies depending upon the software used to open the file. If the data and column headings do not appear aligned, users may wish to try using a different software package (e.g., WordPad) to open the output file. If using Wordpad, it may be helpful to set the view, options, text function for "no wrap;" depending upon the user's computer settings, those choices can help keep the columns aligned properly.

- Idling emission factors and emissions: Because EMFAC2007 did not (as of this writing) provide idling emission factors for all of the fleet, this tool does not report idling emission factors nor does it calculate idling emissions; the capability to perform these analyses may be included in future model versions.

- Known problems for "Year 2005" emission factors: Please note that calendar year 2005 emission estimates have known problems due to problems with EMFAC2007. In general, users should try to avoid doing analyses with a 2005 analysis year (or should consider interpolating from other years to obtain 2005 results).

3. DETAILED USER INSTRUCTIONS

3.1 Launching CT-EMFAC and User Interface Overview

After installation of CT-EMFAC (see Section 2.1 for installation details), launch CT-EMFAC by double clicking the *CT-EMFAC.exe* (icon to the right) in the installation folder or its shortcut on the desktop. Once CT-EMFAC starts, the following interface appears.

CT-EMFAC

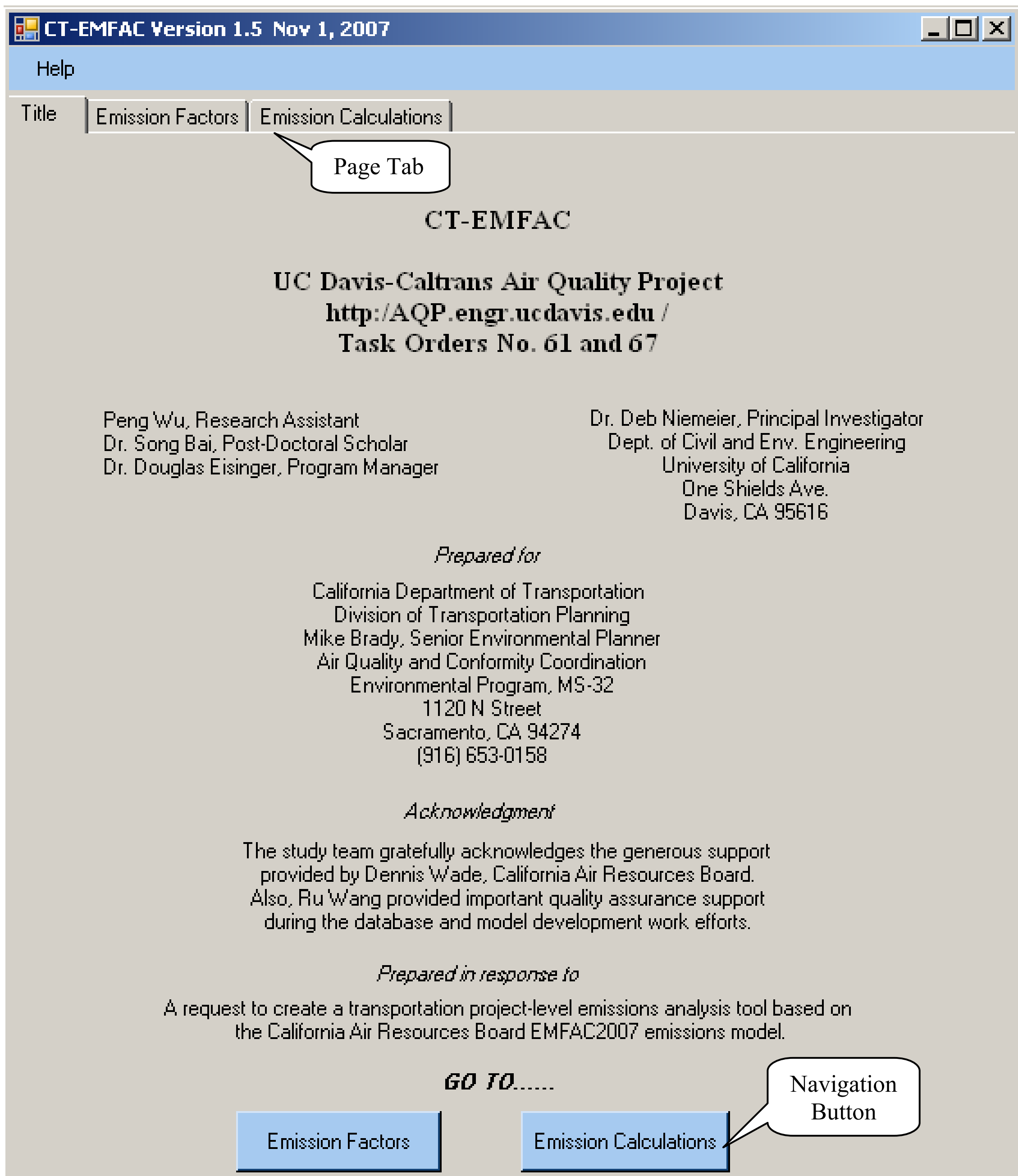
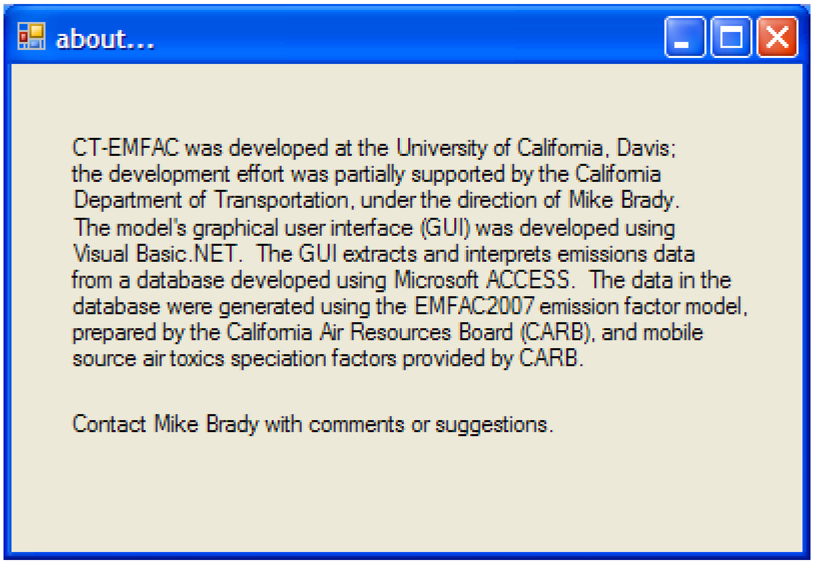


Figure 3-1. Title Page.

Figure 3-1 shows the first screen of CT-EMFAC, Title Page. CT-EMFAC carries only one choice on its "Help, About" menu bar, shown below.

<u>`Help, About:`</u>



CT-EMFAC has three page tabs: Title, Emission Factors, and Emission Calculations. The Title Page is displayed when CT-EMFAC starts. From the Title Page, a user can navigate to either the Emission Factor page or the Emission Calculations page through the navigation buttons. Alternatively, a user can directly click the Emission Factor page tab or the Emission Calculations page tab to go to a target work page.

3.2 Emission Factors Page

The Emission Factors page shown in Figure 3-2 is used to calculate composite emission factors. This page allows a user to create an analysis scenario based on user-specified parameters, such as title, geographic area, analysis year, season, vehicle mix, pollutants of interest, and toxics speciation factors. A single scenario can be used to generate a unique set of composite emission factors. The resulting emission factors are stored in a file, *"scenario title.ef"* , where the filename extension, *".ef",* is used to identify an emission factor file. Table 3-1 describes basic parameters for a scenario. It is important to notice that all of the input parameters are required (not optional) and have to be given a value. An error message will pop up during a scenario run if there is no user input for any parameter. These parameters and other control buttons on this page are described in detail below.

Table 3-1. Description of input parameters on emission factors page.

Input Parameters	Control Type	Required or Optional	Example Input
Scenario Title	Textbox	Required	Sacramento2005
Geographic Area	Radiobutton and Dropdown Listbox	Required	County and Sacramento
Analysis Year	Dropdown Listbox	Required	2005
Season	Radiobutton	Required	Annual
Vehicle Mix	Radiobutton and Textbox	Required	Use Default
Pollutants	Checkbox	Required	TOG, CO2, PM10
Toxics Speciation	Radiobutton	Required	CARB Factors

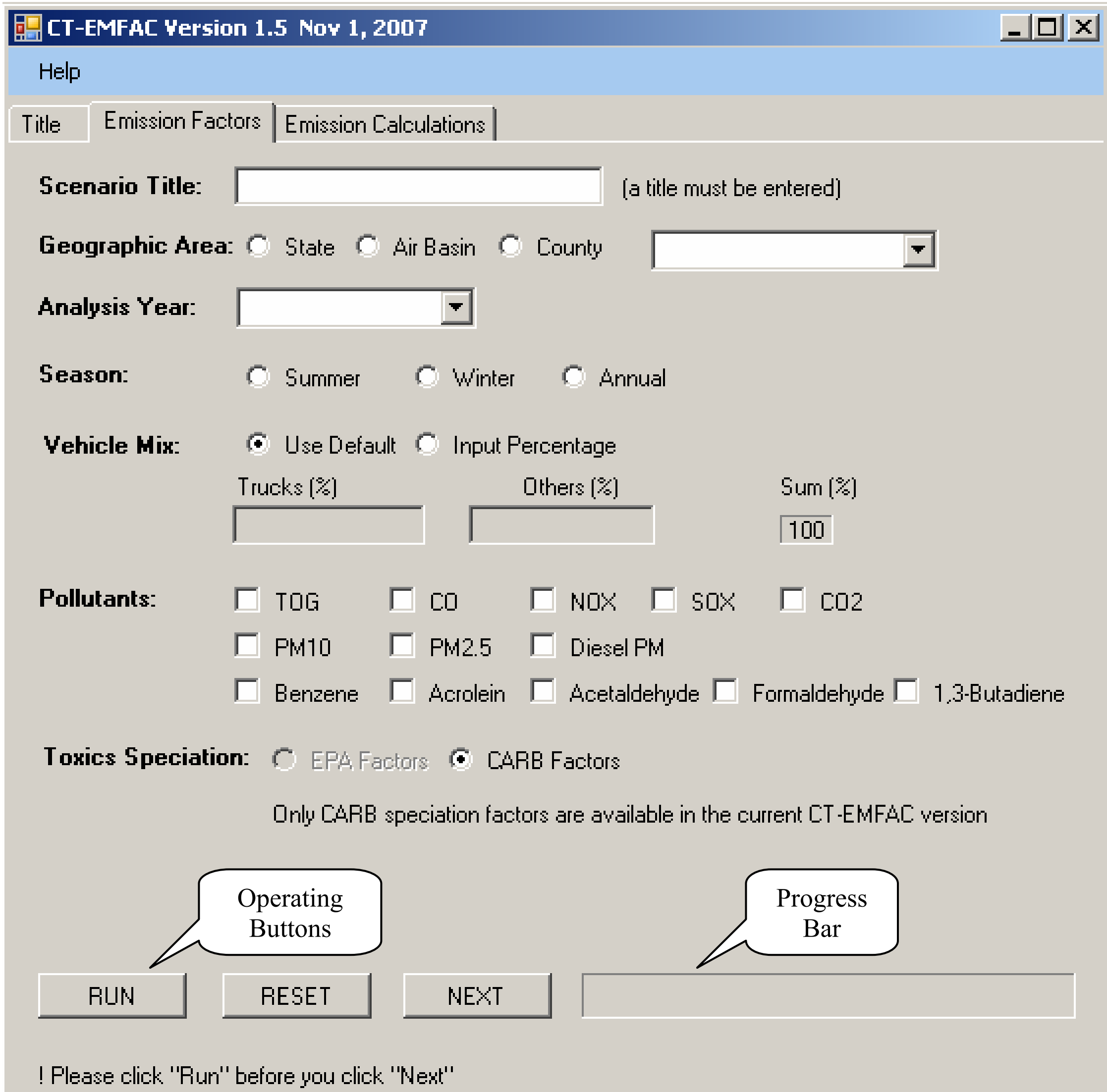
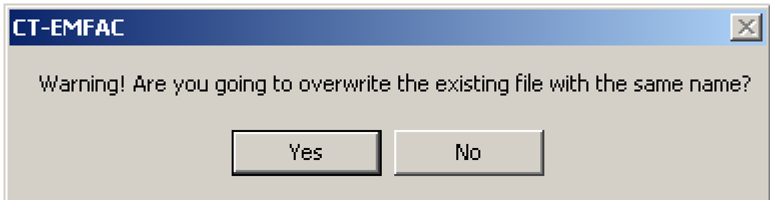


Figure 3-2. Emission Factors Page.

3.2.1 Scenario Title

A scenario title is used as the filename to store the resulting emission factors. For example, if the input text is “Sacrament2005”, the output filename will be *“Sacramento2005.ef”*. Therefore, the title cannot be empty; text must be entered. If the given filename is the same as that of an existing file in the “output” folder, a warning message will appear after pressing the “RUN” button, asking whether you want to overwrite the existing file or not. If the response is “Yes”, the program will proceed to run. Otherwise, an error message will display, indicating you may need to input a new scenario title.



3.2.2 Geographic Area

Based on EMFAC2007, this tool estimates composite emission factors for each geographic area. Emission factors are sensitive to area-specific data, such as vehicle population, mileage accrual, temperature, relative humidity, fuel RVP, and I/M programs. Therefore, users need to specify a scenario for a specific air basin, county, or statewide application. The choice of a geographic area is done with the combination of a radiobutton and a dropdown listbox. If the “State” option is chosen, the dropdown listbox will automatically disable. In the case of choosing “Air Basin”, the dropdown listbox will list all of the 15 air basins alphabetically as follows.

```
List of 15 Air Basins
Great Basin Valleys
Lake County
Lake Tahoe
Mojave Desert
Mountain Counties
North Central Coast
North Coast
Northeast Plateau
Sacramento Valley
Salton Sea
San Diego
San Francisco Bay Area
San Joaquin Valley
South Central Coast
South Coast
```

If the area type selection is “County”, users can choose from a list of 77 options, 58 of which are specific to individual counties in California. There are eight counties located in more than one air basin. In addition to providing county-average emission factors for each of these eight counties, CT-EMFAC also provides emission factors for each county by its air basin sub-areas. Shown below (Table 3-2) are the eight counties and their air basin sub-areas, which account for the remaining 19 options.

Table 3-2. Counties that cover portions of air basins.

County	Air Basin Parts
El Dorado	Lake Tahoe(LT), Mountain Counties(MC)
Kern	San Joaquin Valley(SJV), Mojave Desert(MD)
Los Angeles	South Coast(SC), Mojave Desert(MD)
Placer	Lake Tahoe(LT), Mountain Counties(MC), Sacramento Valley(SV)
Riverside	South Coast(SC), Salton Sea(SS), Mojave Desert Air Quality District(MDAQ), South Coast Air Quality District(SCAQ)
San Bernardino	South Coast(SC), Mojave Desert(MD)
Solano	Sacramento Valley(SV), San Francisco Bay Area(SF)
Sonoma	North Coast(NC), Francisco Bay Area(SF)

3.2.3 Analysis Year

CT-EMFAC can generate composite emission factors for a given calendar year between **2002 and 2040**. For different calendar years, EMFAC2007 assumes different distributions of vehicle model year, technology type, and mileage accrual. You need to select a target calendar year from the dropdown list. Please be alerted that 2005 emission factors have known problems due to problems with EMFAC2007; users should try to avoid doing analyses with a 2005 analysis year.

3.2.4 Season

Emission factors related to meteorological conditions (e.g., temperature and relative humidity) vary by month and season. In an input scenario, you will need to choose a season. Season is defined as summer, winter, or annual average. The summer season is often selected for estimating ozone precursors. CO analysis is usually conducted in the winter season. PM analysis can be done in different times of year. Annual average represents an average of all the monthly conditions.

3.2.5 Vehicle Mix

For a selected geographic area of interest, users can choose to use either the default vehicle mix for the area or they can input a project-specific vehicle mix in terms of percentages of trucks and others (i.e., nontrucks). This tool splits vehicles into two groups: medium-duty and above vehicles (i.e., trucks) and everything else (i.e., nontrucks or others). When a user selects either the default fleet mix, or defines the percent of the fleet equal to trucks, CT-EMFAC interprets the truck percentage to include **both diesel and non-diesel trucks**; the tool then automatically apportions the truck fleet into diesel- and non-diesel fractions. The tool then uses the diesel portion of the truck fleet to calculate diesel PM emission factors.

EMFAC2007 estimates emission factors for 13 separate classes of vehicles by vehicle type and weight. These classes are listed in Table 3-3. Composite emission factors are calculated based on EMFAC default assumptions concerning the vehicle mix of the 13 vehicle classes. For project analysis purposes, the user has the option of varying the fraction of the subject vehicle fleet that is trucks vs. nontrucks. If no user-specified fractions are input, the model employs EMFAC defaults for the region being evaluated.

The default choice of vehicle mix is “Use Default”. If a user chooses “Input Percentage”, the two previously disabled textboxes become active to accept inputs for “Trucks (%)” and “Others (%)”. The textbox of “Sum(%)” is not editable and is preset as 100, reminding users that the total of both percentages should be 100%. The number in the “Sum(%)” will change accordingly based on user-defined percentages. If the total of input percentages is not 100, an error message will pop up during a scenario run.

As noted earlier, “Trucks” are defined as medium-duty trucks and above; these translate to vehicle class codes T3-T7 in Table 3-3. The remaining eight vehicle classes are defined as “Others”, including passenger cars, light duty trucks (T1 and T2), various buses, motorcycles, and motor homes. It is important to understand the CT-EMFAC definitions of “Trucks” and “Others” when you input their corresponding percentages. The most important point to remember is that the “**Trucks**” percentage refers to **all trucks, both gasoline- and diesel-powered**. Once a truck percent is input, the model uses EMFAC default data to apportion the trucks by fuel type.

Table 3-3. Vehicle classes modeled in EMFAC2007.

Vehicle Class	**Fuel Type**	**Code**	**Description**	**Weight Class**	**Abbr.**	**Vehicle Mix**
1	gas, diesel, electric	PC	Passenger Cars	All	LDA	
2	gas, diesel, electric	T1	Light-Duty Trucks	0-3750	LDT1	Others
3	Gas, Diesel	T2	Light-Duty Trucks	3751-5750	LDT2	
4	Gas, Diesel	T3	Medium-Duty Trucks	5751-8500	MDV	
5	Gas, Diesel	T4	Light-Heavy-Duty Trucks	8501-10000	LHDT1	
6	Gas, Diesel	T5	Light-Heavy-Duty Trucks	10001-14000	LHDT2	Trucks
7	Gas, Diesel	T6	Medium-Heavy-Duty Truck	14001-33000	MHDT	
8	Gas, Diesel	T7	Heavy-Heavy-Duty Trucks	33001-60000	HHDT	
9	Gas, Diesel	OB	Other Buses	All	OB	
10	Diesel	UB	Urban Buses	All	UB	
11	Gas	MC	Motorcycles	All	MCY	Others
12	Gas, Diesel	SB	School Buses	All	SBUS	
13	Gas, Diesel	MH	Motor Homes	All	MH	

3.2.6 Pollutants

CT-EMFAC is able to obtain emission factors for the following pollutants:

- Six primary criteria pollutants– Total Organic Gases (TOG), Carbon Monoxide (CO), Nitrogen Oxides (NOx), Oxides of Sulfur (SOx), Particulate Matter 10 microns or less in diameter (PM10), and Particulate Matter 2.5 microns or less in diameter (PM2.5);
- One greenhouse gases– Carbon Dioxide (CO2); and
- Six MSATs– Diesel PM, Formaldehyde, Acetaldehyde, Benzene, 1,3-Butadiene, and Acrolein.

Users can select from among the available pollutants of interest by turning on the corresponding checkboxes.

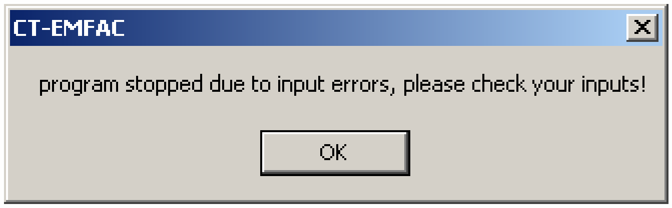
3.2.7 Toxics Speciation

The default choice of toxics speciation factors is “CARB Factors”. Users do not need to change the default setup since the other option, “EPA Factors”, is unavailable in this version of CT-EMFAC. The toxics speciation factors embedded in CT-EMFAC were supplied by CARB; they are not available in EMFAC2007. As used by CT-EMFAC, the speciation factor represents the ratio of emissions of a specific MSAT to TOG emissions. (Future versions of CT-EMFAC may supply an option to use EPA speciation factors, depending upon their availability and applicability in California).

3.2.8 Operating Buttons

There are three operating buttons at the bottom of the Emission Factors page: “RUN”, “RESET”, and “NEXT”. Click “RUN” to start the calculation; you will see a pop-up message as follows.

After clicking “OK”, CT-EMFAC will first check the validity of the input scenario and then start to query emission factors from the database. This running process may take several minutes to complete. If a computer has a relatively low-speed CPU and smaller RAM, the running time will be longer. A progress bar adjacent to the “NEXT” button displays run progress. However, if any of the input parameters is invalid and causes running errors, the message below will appear. In this case, the program stops running, and the user needs to check their inputs.



After a successful run, a message box saying “This program executed successfully” pops up. Then, users can go to the installation folder and find the output file entitled “*scenario title.ef”* in the *“output”* folder.

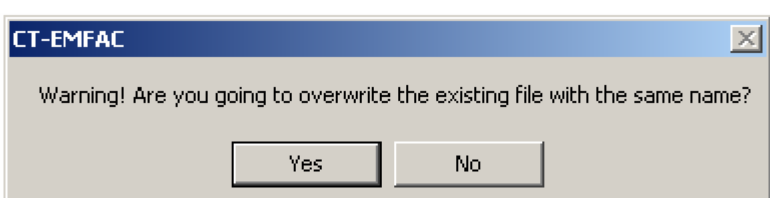
When a new scenario run is needed, users should click the “RESET” button to clear all of the input parameters on the Emission Factors page. Click “NEXT” to calculate total project emissions using the “Emission Calculations” page. To calculate emissions based on the current emission factors scenario, users must click “RUN” to obtain emission factors before proceeding to click “NEXT”. Equivalently, users can click the “Emission Calculations” tab to activate the Emission Calculations page.

3.3 Emission Calculations Page

The Emission Calculations page shown in Figure 3-3 is designed to calculate project-level emissions inventories based on the composite emission factors obtained from the Emission Factors page. This page allows a user to input project-specific travel activities, such as total VMT, roadway length, traffic volume, hours of vehicle activity, and VMT and speed distributions. The calculated emissions are stored in a file named *“scenario title.ec”* , where the filename extension, *“.ec”,* refers to emissions calculations. The storing path of the *“scenario title.ec”* is the same as that of the chosen emission factors file. The following is a detailed description of the user inputs.

3.3.1 Scenario Title

A scenario title is used as the name of a file storing the resulting emission factors. For example, if the input text is “Sacrament2005”, the output filename will be *“Sacramento2005.ef”*. The title is not optional; it must be given. If the given filename is the same as that of an existing file in the output folder, a warning message (see below) will appear when clicking the “RUN” button. If the user response to the warning is “Yes”, the program will continue to run while overwriting the existing file with the same name. Otherwise, an error message will display and the program stops running. In this case, the user will have to rename the scenario title.



3.3.2 Emission Factors

Users can either use the “Current” emission factors or “Choose From a Saved Scenario” to calculate emissions. The “Current” option uses the emission factors generated from the most recent scenario run on the Emission Factors page. In the case of choosing the “Current” option, users should make sure that they have clicked “RUN” on the Emission Factors page so that an output file of emission factors has been created. When “Current” is selected, users will notice that the complete path of the current emission factors file displays in the textbox to the right.

If a user prefers to use emission factors from a previously saved scenario in any folder, select “Choose From a Saved Scenario”. Once the “Choose From a Saved Scenario” is selected, the “File Locating Button” in Figure 3-3 is activated. A user can then navigate to the target emission factors file. After the target file is located, its complete path appears in the textbox next to the button.

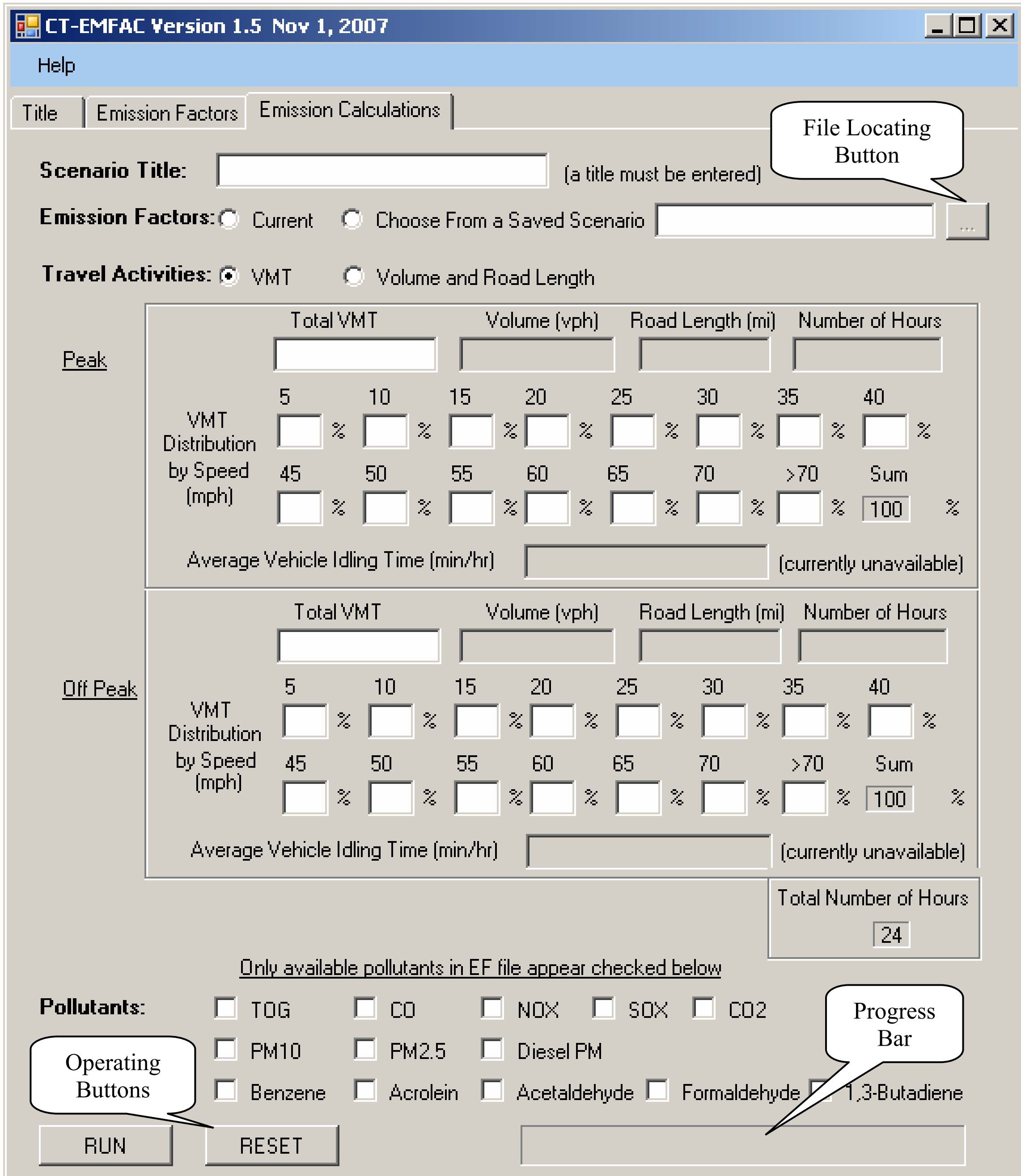


Figure 3-3. Emission Calculations Page.

3.3.3 Travel Activities

In addition to composite emissions factors obtained from the Emission Factors page, CT-EMFAC requires project-specific travel activities to calculate emissions. The travel activities include total VMT, roadway length, traffic volume, traffic time period (i.e. peak hours vs. off peak), and VMT and speed distributions. The input of travel activities is controlled by radiobuttons and textboxes.

First, select either "VMT" or "Volume and Road Length", depending on the data available. The default option is "VMT". If VMT is unknown, users can choose "'Volume and Road Length" as an alternative, which will enable the following textboxes: "Volume (vph)", "Road Length (mi)" and "Number of Hours", but disable the textbox, "Total VMT".

If a user wants to calculate emissions for a whole day, they are asked to input both "Peak" and "Offpeak" travel activities. Notice that the textbox "Total Number of Hours" is 24 by default, which reminds users that the sum of values in the "Number of Hours" textboxes for "Peak" and "Offpeak" time periods should equal 24. However, a user is only interested in one particular time period rather than a whole day, the sum does not have to be 24 when running the model.

In a series of textboxes labeled as "5, 10, …, >70", users need to input VMT percentages by speed for a given time period. For instance, during "Peak", the user can input 70 for the "45" textbox and 30 for the "60" textbox, which represents a VMT-speed distribution of 70% at 45 mph and 30% at 60 mph. It is important to keep in mind that the sum of these input percentages for a particular time period has to be "100". Otherwise, an error message will pop up during a scenario run. Also, please note that users do not need to input anything if the values are zeros; they may just leave the corresponding textboxes blank.

The input of "Average Vehicle Idling Time (min/hr)" is disabled in the current version of CT-EMFAC. The reason is that, as of this writing, EMFAC2007 does not provide idling emission factors for all of the fleet. Thus, this tool does not report idling emission factors nor does it calculate idling emissions. The capability to perform these analyses may be included in future versions.

3.3.4 Pollutants

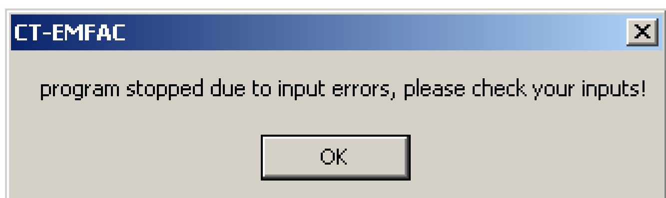
Users do not need to do anything in this step. This step is only designed to show users the available pollutants from a selected emission factors file. That is, only the pollutants that appear as checked will be included in the emissions calculations.

3.3.5 Operating Buttons

Click “RUN” at the bottom to start the calculation; the scenario run should be done promptly. After the scenario run is done, the emissions inventory output file, *“scenario title.ec”*, can be found in the “output” folder if the user chooses “Current” emission factors. However, if the user selects “Choose From a Saved Scenario”, the output file will appear in the same folder where the saved scenario locates. In the event of inappropriate or missing inputs, an error message, “program stopped due to input errors, please check your inputs”, may come up. Additionally, if a user wants to start a new scenario run, they must click the “RESET” button to clear all of the input parameters on the Emission Calculations page.

3.4 Dealing with Error Messages

The following error message is displayed when any unexpected condition occurs during a scenario run. In this case, CT-EMFAC stops running, and user intervention is required. Some common causes and their solutions are given as follows for an emission factors generation scenario run and an emissions calculations scenario run, respectively.



Common error causes in generating emission factors:

- Missing parameters: every parameter, such as “Scenario Title”, “Geographic Area”, “Analysis Year”, “Season”, or “Pollutants”, has to be given a value. For example, either empty “Scenario Title” or unselected “season” will cause running errors.
- Duplicate “Scenario Title”: CT-EMFAC uses “Scenario Title” as the filename of the output file of a scenario run. The output file, *“Scenario Title.ef”*, is saved in the “output” folder. If the filename is the same as an existing file name in that folder, a warning message will pop up, asking the user whether to overwrite the existing file or not.
- Inequality: if a user defines the “Vehicle Mix”, then the sum of “Trucks (%)” and “Others (%)” must be 100. If the sum of the input percentages is not 100, an error message will appear after clicking “RUN”.

Common error causes in emissions calculations:

- Missing parameters: every parameter, such as “Scenario Title”, or “Emission Factors”, must be given a value. For example, either an empty “Scenario Title” or an unselected “Emission Factors” file will cause run errors.

- Duplicate "Scenario Title": CT-EMFAC uses "Scenario Title" as the filename of the output file of emissions calculations. The output file, *"Scenario Title.ec"*, is saved in the same folder where the chosen emission factors input file is located. If the filename is identical to that of an existing file in the target folder, a warning message will pop up, asking the user whether to overwrite the existing file or not. If the response to the warning message is "No", the error message will pop up, asking the user to check inputs.
- Inequality: when specifying "Travel Activities", users must make sure that the sum of the input VMT distribution percentages by speed for a particular time period is "100". Otherwise, an error message will display during a scenario run.
- Invalid "Emission Factors" input file: the chosen emission factors input file has to be generated by CT-EMFAC. If a user chooses to use "Current" emission factors but does not actually "RUN" the input scenario on the Emission Factors page before moving to the Emission Calculations page, the error message will come up because the emission factors file does not exist yet.

3.5 CT-EMFAC Output File

Before proceeding to read the details of CT-EMFAC output files, there are three key points users need to know. They have been introduced previously. We restate them below:

- After a successful scenario run, the resulting emission factors named *"scenario title.ef"* can be found in the "output" folder located in the directory where CT-EMFAC is installed. The calculated emissions are saved in the file, *"scenario title.ec"*, which could be in either the "output" folder or any other folder where the chosen emission factors input file is located, depending on the selection in "Emission Factors" on the Emission Calculations page.
- The CT-EMFAC output files are in *".txt"* format. They can be opened with any *txt* editors, such as, Notepad or WordPad. The legibility and organization of the output file varies depending upon the software used to open the file. If the data and column headings do not appear aligned, users may wish to try using a different software package (e.g., UltraEdit) to open the output file. If using Wordpad, users may find that setting their View, Options, Text function for "no wrap" helps keep columns properly aligned.
- Please note that idling emission factors and emissions are currently not reported in the output files. Since EMFAC2007 does not provide idling emission factors for all of the fleet, this tool does not report idling emission factors nor does it calculate idling emissions; the capability to perform these analyses may be included in future versions.

This discussion uses two example output files to illustrate the organization of CT-EMFAC output. The files can be found in:

```
Installation Path\CT-EMFAC\output\ sacramentoEmfac.ef
Installation Path\CT-EMFAC\output\ sacramentoEmfac.ec
```

The content of *"sacramentoEmfac.ef"* is shown in Example 1. As we can see, an emission factors output file is organized into four sections: (I) Header, (II) Running Exhaust Emission Factors, (III) Idling Emission Factors, and (IV) Evaporative Running Loss Emission Factors. Section I includes key scenario parameters, such as scenario year, season, and geographic area. Additionally, information regarding the current CT-EMFAC version, and representative temperature and relative humidity for the chosen season is also presented in the header. Section II lists emission factors by pollutant type and speed for running exhaust emissions in grams/mile. Section III is reserved for reporting idling emission factors in future versions of CT-EMFAC. Section IV reports emission factors for evaporative running loss emissions.

Example 2 shows the content of *"sacramentoEmfac.ec"*. An emission calculations output file is divided into five sections: (I) Header, (II) Running Exhaust Emissions, (III) Idling Emissions, (IV) Evaporative Running Loss Emissions, and (V) Total Emissions. Section I includes two parts. The first part is the same as the header information contained in the chosen emissions factor input file. The second part replicates the travel activity inputs used in the Emission Calculations page. In summary, the purpose of Section I is to show users the key input parameters selected for their project-level emissions analysis. Section II shows the calculated running emissions by pollutant type. Emissions by speed bin and total emissions are given in this section. VMT-speed distribution details are also given. Section III is reserved for Idling emissions (empty in the current version). Section IV reports evaporative running loss emissions. Section V is a summary of emissions totals. Emissions totals are shown in terms of grams, kilograms, and U.S. short tons, respectively.

Example 1. CT-EMFAC Emission Factors Output File.

```
Title             :    sacramentoEmfac
Version           :    CT-EMFAC 1.5
Run Date          :    03 October 2007  01:29 PM
Scen Year         :    2005
Season            :    Annual
Temperature       :    65F
Relative Humidity:     56%
Area              :    Sacramento County
```

Section I

```
========================================================================

          Running Exhaust Emissions (grams/mile)
------------------------------------------------------------------------
```

Section II

```
         Pollutant Name    :  TOG_exh

   speed(mph)           Emission Factor

        5                   1.276000
       10                   0.841000
       15                   0.568000
       20                   0.410000
       25                   0.327000
       30                   0.271000
       35                   0.236000
       40                   0.214000
       45                   0.205000
       50                   0.207000
       55                   0.220000
       60                   0.245000
       65                   0.287000
       70                   0.315000
       75                   0.356000


         Pollutant Name    :  SO2

   speed(mph)           Emission Factor

        5                   0.022000
       10                   0.018000
       15                   0.015000
       20                   0.013000
       25                   0.012000
       30                   0.011000
       35                   0.011000
       40                   0.010000
       45                   0.010000
       50                   0.010000
       55                   0.010000
       60                   0.011000
       65                   0.011000
       70                   0.011000
       75                   0.012000
         Pollutant Name    :  PM10

   speed(mph)           Emission Factor

        5                   0.160000
       10                   0.110000
       15                   0.076000
```

Example 1. CT-EMFAC Emission Factors Output File (continued).

```
     20                 0.056000
     25                 0.046000
     30                 0.038000
     35                 0.033000
     40                 0.030000
     45                 0.029000
     50                 0.029000
     55                 0.030000
     60                 0.033000
     65                 0.038000
     70                 0.042000
     75                 0.048000


      Pollutant Name   :  NOX

speed(mph)          Emission Factor

      5                 2.296000
     10                 1.785000
     15                 1.462000
     20                 1.309000
     25                 1.240000
     30                 1.196000
     35                 1.175000
     40                 1.175000
     45                 1.196000
     50                 1.240000
     55                 1.312000
     60                 1.418000
     65                 1.571000
     70                 1.742000
     75                 1.991000


      Pollutant Name   :  CO2

speed(mph)          Emission Factor

      5             1,216.870000
     10               928.068000
     15               735.006000
     20               604.922000
     25               520.087000
     30               462.970000
     35               426.106000
     40               405.071000
     45               397.520000
     50               402.700000
     55               421.303000
     60               455.607000
     65               509.947000
     70               517.763000
     75               530.087000
```

Example 1. CT-EMFAC Emission Factors Output File (concluded).

```
     Pollutant Name    :  CO

   speed(mph)           Emission Factor

         5                 10.258000
        10                  8.196000
        15                  6.798000
        20                  5.823000
        25                  5.137000
        30                  4.640000
        35                  4.289000
        40                  4.061000
        45                  3.948000
        50                  3.960000
        55                  4.123000
        60                  4.493000
        65                  5.173000
        70                  5.786000
        75                  6.838000
```

Section III

```
----------------------------------------------------------------------
          Idling Emissions (grams/idle-hour)  (Currently NOT Available)
----------------------------------------------------------------------

----------------------------------------------------------------------
          Evaporative Running Loss Emissions (grams/minute)
----------------------------------------------------------------------
```

Section IV

```
         Pollutant Name    :  TOG_los

   time(min)           Emission Factor

         1                  0.189000
         2                  0.115000
         3                  0.093000
         4                  0.083000
         5                  0.078000
        10                  0.070000
        15                  0.070000
        20                  0.072000
        25                  0.074000
        30                  0.074000
        35                  0.075000
        40                  0.075000
        45                  0.075000
        50                  0.074000
        55                  0.074000
        60                  0.073000

------------------------------ END-------------------------------------
```

Example 2. CT-EMFAC Emission Calculations Output File.

Section I

```
Title              :       sacramentoEmissions
Version            :       CT-EMFAC 1.5
Run Date           :       03 October 2007  01:30 PM
Scen Year          :       2005
Season             :       Annual
Temperature        :       65F
Relative Humidity  :       56%
Area               :       Sacramento County

Peak User Input    :
                         Total VMT        Volume (vph)     Road Length(mi)     Number of Hours
                             58852
                         VMT Distribution(%) by Speed(mph)
               (mph)     5    10    15    20    25    30    35    40    45    50    55    60    65    70   >75
                   %                                                                                   100
Offpeak User Input:
                         Total VMT        Volume (vph)     Road Length(mi)     Number of Hours

                         VMT Distribution(%) by Speed(mph)
               (mph)     5    10    15    20    25    30    35    40    45    50    55    60    65    70   >75
                   %
====================================================================================================
```

Section II

```
         Running Exhaust Emissions (grams)
----------------------------------------------------------------------------------------------------

        Pollutant Name    :  TOG_exh
```

speed(mph)	Emission Factor(grams/mile)	VMT by Speed	VMT-Speed Distribution (%)	Emissions by Speed
5	1.276000	0.00	0.00	0.000000
10	0.841000	0.00	0.00	0.000000
15	0.568000	0.00	0.00	0.000000
20	0.410000	0.00	0.00	0.000000
25	0.327000	0.00	0.00	0.000000
30	0.271000	0.00	0.00	0.000000
35	0.236000	0.00	0.00	0.000000
40	0.214000	0.00	0.00	0.000000
45	0.205000	0.00	0.00	0.000000

Example 2. CT-EMFAC Emission Calculations Output File (continued).

50	0.207000	0.00	0.00	0.000000
55	0.220000	0.00	0.00	0.000000
60	0.245000	0.00	0.00	0.000000
65	0.287000	0.00	0.00	0.000000
70	0.315000	58,852.00	100.00	18,538.380000
75	0.356000	0.00	0.00	0.000000

Total		58,852.00	100.00	18,538.380000

Pollutant Name : SO2

speed(mph)	Emission Factor(grams/mile)	VMT by Speed	VMT-Speed Distribution (%)	Emissions by Speed
5	0.022000	0.00	0.00	0.000000
10	0.018000	0.00	0.00	0.000000
15	0.015000	0.00	0.00	0.000000
20	0.013000	0.00	0.00	0.000000
25	0.012000	0.00	0.00	0.000000
30	0.011000	0.00	0.00	0.000000
35	0.011000	0.00	0.00	0.000000
40	0.010000	0.00	0.00	0.000000
45	0.010000	0.00	0.00	0.000000
50	0.010000	0.00	0.00	0.000000
55	0.010000	0.00	0.00	0.000000
60	0.011000	0.00	0.00	0.000000
65	0.011000	0.00	0.00	0.000000
70	0.011000	58,852.00	100.00	647.372000
75	0.012000	0.00	0.00	0.000000

Total		58,852.00	100.00	647.372000

Pollutant Name : PM10

speed(mph)	Emission Factor(grams/mile)	VMT by Speed	VMT-Speed Distribution (%)	Emissions by Speed
5	0.160000	0.00	0.00	0.000000
10	0.110000	0.00	0.00	0.000000
15	0.076000	0.00	0.00	0.000000
20	0.056000	0.00	0.00	0.000000
25	0.046000	0.00	0.00	0.000000

Example 2. CT-EMFAC Emission Calculations Output File (continued).

30	0.038000	0.00	0.00	0.000000
35	0.033000	0.00	0.00	0.000000
40	0.030000	0.00	0.00	0.000000
45	0.029000	0.00	0.00	0.000000
50	0.029000	0.00	0.00	0.000000
55	0.030000	0.00	0.00	0.000000
60	0.033000	0.00	0.00	0.000000
65	0.038000	0.00	0.00	0.000000
70	0.042000	58,852.00	100.00	2,471.784000
75	0.048000	0.00	0.00	0.000000
Total		58,852.00	100.00	2,471.784000

Pollutant Name : NOX

speed(mph)	Emission Factor(grams/mile)	VMT by Speed	VMT-Speed Distribution (%)	Emissions by Speed
5	2.296000	0.00	0.00	0.000000
10	1.785000	0.00	0.00	0.000000
15	1.462000	0.00	0.00	0.000000
20	1.309000	0.00	0.00	0.000000
25	1.240000	0.00	0.00	0.000000
30	1.196000	0.00	0.00	0.000000
35	1.175000	0.00	0.00	0.000000
40	1.175000	0.00	0.00	0.000000
45	1.196000	0.00	0.00	0.000000
50	1.240000	0.00	0.00	0.000000
55	1.312000	0.00	0.00	0.000000
60	1.418000	0.00	0.00	0.000000
65	1.571000	0.00	0.00	0.000000
70	1.742000	58,852.00	100.00	102,520.184000
75	1.991000	0.00	0.00	0.000000
Total		58,852.00	100.00	102,520.184000

Pollutant Name : CO2

speed(mph)	Emission Factor(grams/mile)	VMT by Speed	VMT-Speed Distribution (%)	Emissions by Speed
5	1,216.870000	0.00	0.00	0.000000

Example 2. CT-EMFAC Emission Calculations Output File (continued).

10	928.068000	0.00	0.00	0.000000
15	735.006000	0.00	0.00	0.000000
20	604.922000	0.00	0.00	0.000000
25	520.087000	0.00	0.00	0.000000
30	462.970000	0.00	0.00	0.000000
35	426.106000	0.00	0.00	0.000000
40	405.071000	0.00	0.00	0.000000
45	397.520000	0.00	0.00	0.000000
50	402.700000	0.00	0.00	0.000000
55	421.303000	0.00	0.00	0.000000
60	455.607000	0.00	0.00	0.000000
65	509.947000	0.00	0.00	0.000000
70	517.763000	58,852.00	100.00	30,471,388.076000
75	530.087000	0.00	0.00	0.000000

Total		58,852.00	100.00	30,471,388.076000

Pollutant Name : CO

speed(mph)	Emission Factor(grams/mile)	VMT by Speed	VMT-Speed Distribution (%)	Emissions by Speed
5	10.258000	0.00	0.00	0.000000
10	8.196000	0.00	0.00	0.000000
15	6.798000	0.00	0.00	0.000000
20	5.823000	0.00	0.00	0.000000
25	5.137000	0.00	0.00	0.000000
30	4.640000	0.00	0.00	0.000000
35	4.289000	0.00	0.00	0.000000
40	4.061000	0.00	0.00	0.000000
45	3.948000	0.00	0.00	0.000000
50	3.960000	0.00	0.00	0.000000
55	4.123000	0.00	0.00	0.000000
60	4.493000	0.00	0.00	0.000000
65	5.173000	0.00	0.00	0.000000
70	5.786000	58,852.00	100.00	340,517.672000
75	6.838000	0.00	0.00	0.000000

Total		58,852.00	100.00	340,517.672000

Example 2. CT-EMFAC Emission Calculations Output File (concluded).

```
------------------------------------------------------------------------------------------------------
          Idling Emissions (grams) (Currently NOT Available)
------------------------------------------------------------------------------------------------------
```

Section III

```
------------------------------------------------------------------------------------------------------
          Evaporative Running Loss Emissions (grams)
------------------------------------------------------------------------------------------------------

         Pollutant Name   :  TOG_los

              Emission Factor(grams/min)       total running time(hrs)                     Emissions

                                0.073000                        840.74                3,682.453714

------------------------------------------------------------------------------------------------------
          Total Emissions
------------------------------------------------------------------------------------------------------

Pollutant Name       Total Emissions (grams)   Total Emissions (Kilograms)     Total Emissions (US Tons)

            TOG                22,220.833714                     22.220834                0.024494276
            SO2                   647.372000                      0.647372                0.000713605
           PM10                 2,471.784000                      2.471784                0.002724675
            NOX               102,520.184000                    102.520184                0.113009158
            CO2            30,471,388.076000                 30,471.388076               33.588955736
             CO               340,517.672000                    340.517672                0.375356481

--------------------------------------------------- END----------------------------------------------
```

Section IV

Section V

APPENDIX A. METHODOLOGY

CT-EMFAC Development Framework

This section provides an overview of how CT-EMFAC was developed. As shown in Figure A-1, the process of developing CT-EMFAC comprised three major steps:

- Step 1: ACCESS database populated with emission factors EMFAC2007
- Step 2: User Interface developed using Microsoft Visual Basic .NET
- Step 3: Core modules developed using Microsoft Visual Basic .NET

The first step of the model development effort was to generate a database of intermediate composite emission factors using the newest emission factor model, EMFAC2007. The database was derived from EMFAC2007's Impact Rate Detail output files with extension ".rtl". An "*.rtl" output file provides detailed emission factors corresponding to combinations of temperature, relative humidity, speed, calendar year, vehicle class, and technology type. Such a file is specific to one particular geographic area. The database was created to encompass 39 calendar years (2002 to 2040) and 93 geographic areas (state, individual air basins, and various county and sub-county areas). The model development team generated 93 such *.rtl output files.

As part of the database development effort, we provided users with the ability to modify fleet composition. In practice, transportation project analysts have access to, or can estimate, the fraction of the vehicle fleet expected to be trucks. More detailed assessments of fleet mix, such as the age distribution of the fleet, are usually not available when completing transportation project-level air quality assessments. Thus, CT-EMFAC was developed to allow users to modify the fraction of a fleet equal to trucks. The database development effort created intermediate composite emission factors (i.e., composite truck emission factors and composite nontruck emission factors) to significantly reduce data size without losing modeling accuracy in practical applications.

The second step was the design of a Graphical User Interface (GUI), composed of two main pages: an Emission Factors, and an Emission Calculations page. The Emission Factors page allows users to create an analysis scenario based on user-specified parameters, such as title, geographic area, analysis year, season, vehicle mix, pollutants of interest, and options related to selection of toxics speciation factors. A scenario can be used to generate a set of composite emission factors. The Emission Calculations page is designed to calculate project-level emissions inventories based on the composite emission factors obtained from the Emission Factors page. The Calculations page allows for inputs of project-specific travel activities, such as total VMT, roadway length, traffic volume, travel activity in hours, and VMT and speed distributions.

The third step of this CT-EMFAC software development effort consisted of the creation and implementation of three components used to communicate between the GUI and the embedded database. The first component calculates composite emission factors by combining intermediate truck and nontruck composite emission factors based on a user-specified vehicle mix. In order to obtain diesel PM emission factors, the second component translates the user-specified truck and nontruck percentages into diesel and nondiesel percentages by using area and year-specific travel fractions stored in the database. The third component uses project-specific travel activities, coupled with composite emission factors generated by CT-EMFAC, to calculate emissions.

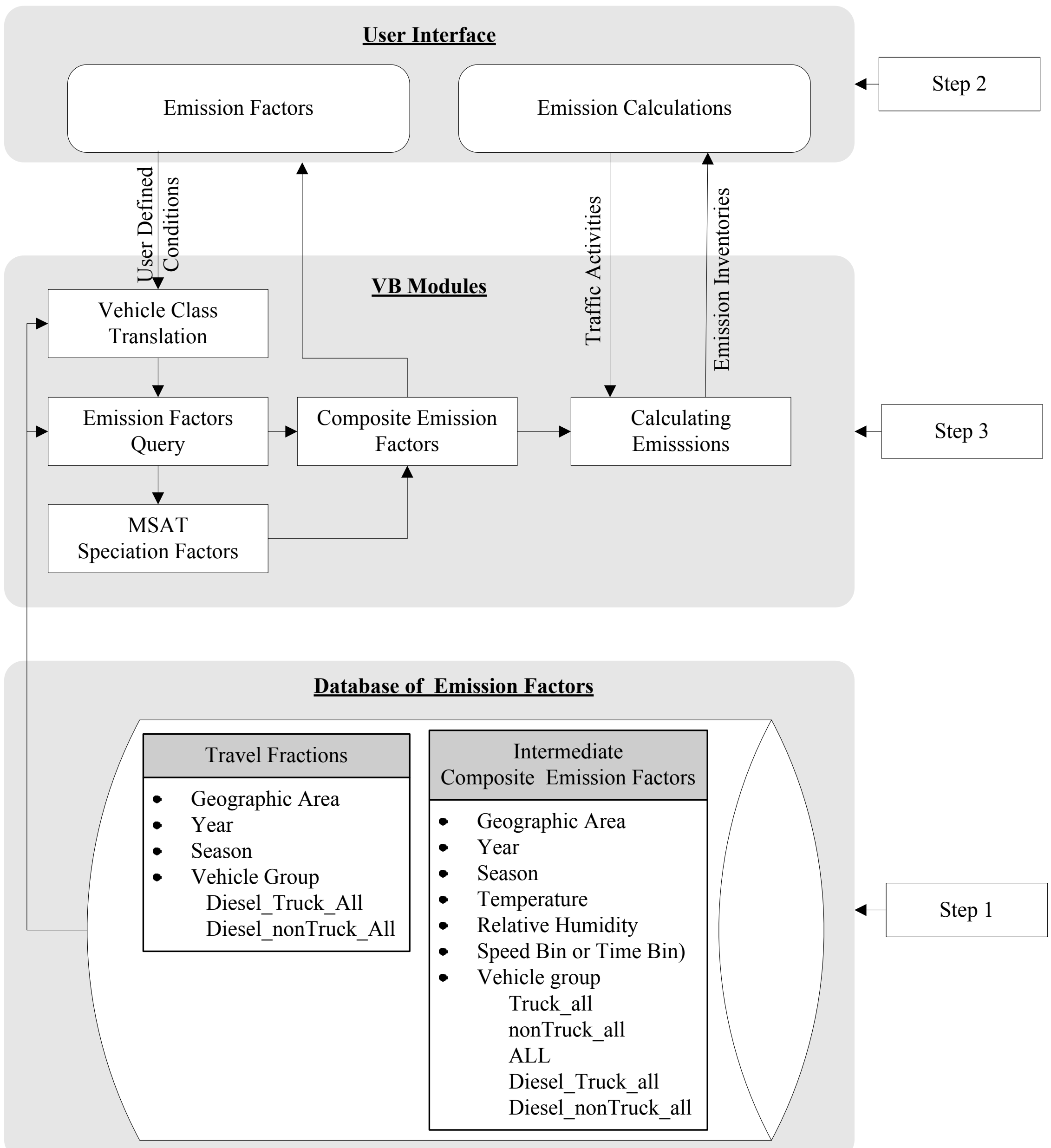


Figure A-1. CT-EMFAC development framework.

Developing Intermediate Composite Emission Factors

The methods used to develop intermediate composite emission factors varied by pollutant type. Six primary criteria pollutants (i.e., TOG, CO, NOx, SOx, PM10, and PM2.5) and CO2 shared a common method; five MSATs, including Formaldehyde, Acetaldehyde, Benzene, 1,3-Butadiene, and Acrolein, used the same method; Diesel PM, another MSAT, used a different method which is introduced in another section. The methods of developing intermediate composite emission factors for trucks and nontrucks for criteria pollutants, CO2, and five MSATS are introduced as follows.

Equations A-1 and A-2 were used to calculate truck composite emission factors for six primary criteria pollutants and CO2. Equation A-1 calculates truck composite emission factors by taking a weighted average of emission factors of medium duty trucks and above based on their relative travel fraction ratios. The relative travel fraction ratios are calculated using Equation A-2. For example, a travel fraction ratio for medium-duty trucks (T3) is the proportion of its travel when compared to total travel by vehicles in classes T3-T7. Both emission factors by vehicle type and travel fractions by vehicle type are obtained from EMFAC2007 *.rtl output. The calculation of intermediate composite emission factors for nontrucks (Equations A-3 and A-4) is similar to that of truck composite emission factors except different emission factors and travel fractions are used.

The calculation of intermediate composition emission factors for the five gaseous MSATs uses toxics speciation factors supplied by CARB. A speciation factor represents the ratio of emissions of a specific MSAT to total TOG emissions. As shown in Equation A-5, we can obtain emission factors by vehicle class and technology type for a particular MSAT by multiplying TOG emission factors by speciation factors. Equation A-6 uses travel fraction ratios of individual vehicle classes and technology groups as weighting factors (i.e., $vmtTF_{vec,tech}$) to calculate truck composite emission factors. Similarly, we can compute nontruck composite emission factors for MSATs.

Note that, in the above steps, the calculation of intermediate emission factors is specific to each calendar year, season, geographic area, and emissions process (i.e., running exhaust, idling, or running loss).

$$EF_{Truck} = \sum_{vec=3}^{vec=7} EF_{vec} \times vmtTF_{vec}$$ Equation A-1

$$vmtTF_{vec} = (relativeVMT)_{vec} / \sum_{vec=3}^{vec=7} (relativeVMT)_{vec}$$ Equation A-2

Where,

EF_{Truck}	=	intermediate composite emission factors for trucks;
EF_{vec}	=	emission factor by vehicle type;
$vmtTF_{vec}$	=	travel fraction ratio relative to all the trucks;
$relativeVMT_{vec}$	=	travel fraction relative to the whole fleet by vehicle type; and
vec	=	medium duty trucks and above, consisting of T3-T7 as coded in Table 3-3.

$$EF_{Other} = \sum_{vec} EF_{vec} \times vmtTF_{vec}$$ Equation A-3

$$vmtTF_{vec} = (relativeVMT)_{vec} / \sum_{vec} (relativeVMT)_{vec}$$ Equation A-4

Where,

EF_{Other}	=	intermediate composite emission factors for nontrucks;
EF_{vec}	=	emission factor by vehicle type;
$vmtTF_{vec}$	=	travel fraction ratio relative to all the nontrucks;
$relativeVMT_{vec}$	=	travel fraction relative to the whole fleet by vehicle type; and
vec	=	eight types of nontruck vehicles (i.e., excluding T3-T7) in Table 3-3.

$$MSAT_{Truck} = \sum_{vec=3}^{vec=7} \sum_{tech=1}^{tech=3} (MSAT_{vec,tech} \times vmtTF_{vec,tech})$$ Equation A-5

$$MSAT_{vec,tech} = TOG_{vec,tech} \times SPEC_{vec,tech}$$ Equation A-6

$$vmtTF_{vec,tech} = relativeVMT_{vec,tech} / \sum_{vec=3}^{vec=7} \sum_{tech=1}^{tech=3} relativeVMT_{vec,tech}$$ Equation A-7

Where,

$MSAT_{Truck}$	=	intermediate MSAT composite emission factors for trucks;
$MSAT_{vec,tech}$	=	MSAT emission factor by vehicle class and technology type;
$TOG_{vec,tech}$	=	TOG emission factor by vehicle class and technology type;
$SPEC_{vec,tech}$	=	speciation factor by vehicle class and technology type;
$vmtTF_{vec,tech}$	=	travel fraction ratio of specific vehicle class and technology type relative to all the trucks;
$relativeVMT_{vec,tech}$	=	travel fraction relative to the whole fleet by vehicle class and technology type; and
vec	=	vehicle class type (e.g., medium trucks and above, or T3-T7); and
tech	=	technology type (e.g., catalytic, noncatalytic, and diesel).

Developing Composite Emission Factors

We obtained intermediate composite emission factors by categorizing 13 vehicle classes into two groups: trucks and others (i.e., nontrucks). The next step involved calculating fleet-average composite emission factors using either a user-defined, project-specific vehicle mix in terms of trucks and others, or EMFAC fleet mix defaults. "Trucks" is defined as medium duty trucks and above, which include T3-T7 coded in Table 3-3. The remaining eight vehicle classes are defined as "Others", including passenger cars, light duty trucks (T1 and T2), various buses, motorcycles, and motor homes.

Equation A-8 below is used to calculate project-specific composite emission factors based on user-specified percentages of trucks and nontrucks. This equation applies to any type of pollutant except for diesel PM.

$$EF_{fleet} = EF_{Truck} \times VEHMIX_{Truck} + EF_{Other} \times VEHMIX_{other} \qquad \text{Equation A-8}$$

Where,

EF_{fleet} = fleet-average composite emission factor;

$VEHMIX_{Truck}$ = percentage of trucks on road;

$VEHMIX_{other}$ = percentage of non-truck vehicles on road;

EF_{Truck} = intermediate composite emission factors for trucks; and

EF_{Other} = intermediate composite emission factors for non-trucks.

Developing Diesel PM Composite Emission Factors

The development of diesel PM composite emission factors is different from that of the other pollutants as introduced in the previous two sections. As opposed to obtaining intermediate composite emission factors for trucks and nontrucks, the calculation of diesel PM composite emission factors needs to first obtain intermediate composite emission factors in terms of diesel trucks and diesel nontrucks. As shown in Equation A-9, diesel truck composite emission factors were calculated by taking a weighted average of all of the emission factors for medium-duty and above diesel trucks. The weighting factors are the ratios of travel fractions of individual diesel truck classes to the total fraction of all of the diesel trucks (Equation A-10). This method of developing diesel truck composite emission factors is similar to the method used to develop truck composite emission factors; the difference lies in that we focus on diesel trucks only in calculating diesel truck composite emission factors. By the same means, we can calculate diesel nontruck intermediate composite emission factors, where we consider all of the diesel vehicles in the nontruck portion of the whole fleet.

After having obtained diesel truck and diesel nontruck composite emission factors, we combine them with percentages of diesel trucks and diesel nontrucks in the whole fleet to calculate fleet-average diesel PM composite emission factors. The calculation is shown in Equation A-11. In the equations, $(VEHMIX_{Truck} \times dieselPer_{Truck})$ and $(VEHMIX_{other} \times dieselPer_{other})$, we calculate the percentages of diesel trucks and diesel nontrucks in the whole fleet, respectively. $VEHMIX_{Truck}$ and $VEHMIX_{other}$ reflect a user-defined, project-specific vehicle mix (if users do not specify these percentages, the model derives comparable values from EMFAC defaults). Because "Trucks" and "Others" defined in CT-EMFAC include both diesel and nondiesel vehicles, we need to use $dieselPer_{Truck}$ and $dieselPer_{other}$ to find the portions of diesel vehicles in both the truck group and the nontruck group. $dieselPer_{Truck}$ and $dieselPer_{other}$ vary by analysis year and are derived from detailed travel fractions provided by EMFAC2007's *.rtl outputs.

$$EF_{dieselTruck} = \sum_{vec=3}^{vec=7} EF_{vec} * vmtTF_{vec}$$ Equation A-9

$$vmtTF_{vec} = (relativeVMT)_{vec} / \sum_{vec=3}^{vec=7} (relativeVMT)_{vec}$$ Equation A-10

Where,

$EF_{dieselTruck}$ = PM composite emission factors for diesel trucks ;

EF_{vec} = PM emission factor by diesel vehicle class;

$vmtTF_{vec}$ = travel fraction ratio relative to all of the diesel trucks;

$relativeVMT_{vec}$ = travel fraction relative to the whole fleet by vehicle type; and

vec = medium duty and above diesel trucks, including T3-T7.

$$EF_{fleet} = EF_{dieselTruck} \times (VEHMIX_{Truck} \times dieselPer_{Truck}) + EF_{dieselOther} \times (VEHMIX_{other} \times dieselPer_{other})$$ Equation A-11

Where,

EF_{fleet} = fleet-average diesel PM composite emission factor;

$VEHMIX_{Truck}$ = percentage of trucks on road;

$VEHMIX_{other}$ = percentage of non-truck vehicles on road;

$dieselPer_{Truck}$ = percentage of diesel trucks in all of the trucks;

$dieselPer_{other}$ = percentage of diesel vehicles in all of the nontrucks;

$EF_{dieselTruck}$ = diesel truck intermediate composite emission factor; and

$EF_{dieselOther}$ = diesel nontruck intermediate composite emission factor.

Calculating Emissions

Using the methods described in the previous sections, CT-EMFAC generates a set of composite emission factors based on user-specified parameters, such as geographic area, analysis year, season, vehicle mix, pollutants of interest, and selection of toxics speciation factors. The composite emission factors vary by speed bin or by time bin depending pollutant types. We can calculate emissions by combining composite emission factors with project-specific travel activities, such as total VMT, travel activity hours, and VMT and speed distributions.

A general form of the equation used to calculate emissions for each emissions process is given as follows.

Running exhaust emissions:

*Emissions Inventory [grams] = (Emission rates [grams/mile]) * (Vehicle Miles Traveled [miles])*

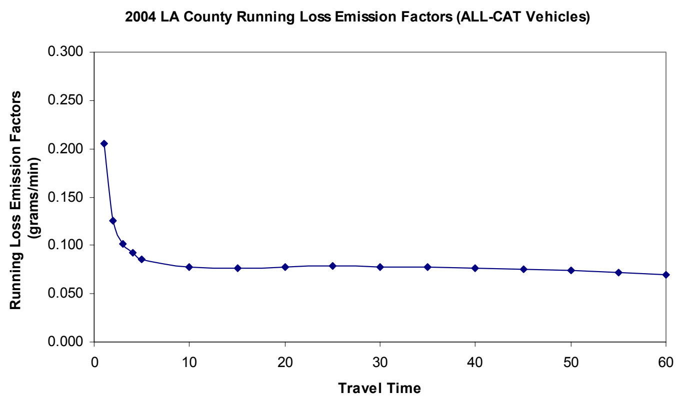
Idling emissions:

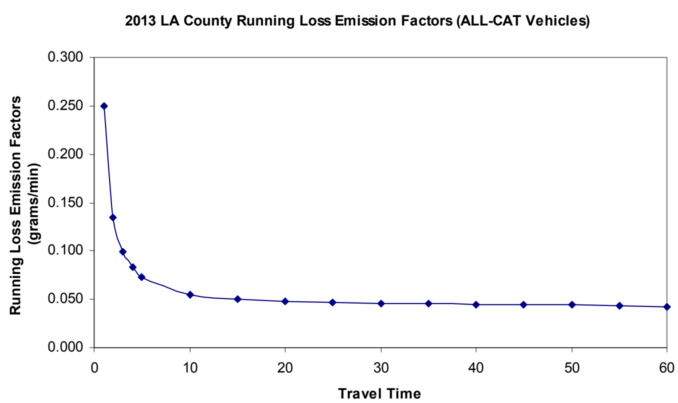
*Emissions Inventory [grams] = (Emission rates [grams/hour]) * (Vehicle Iding Time [hours])*

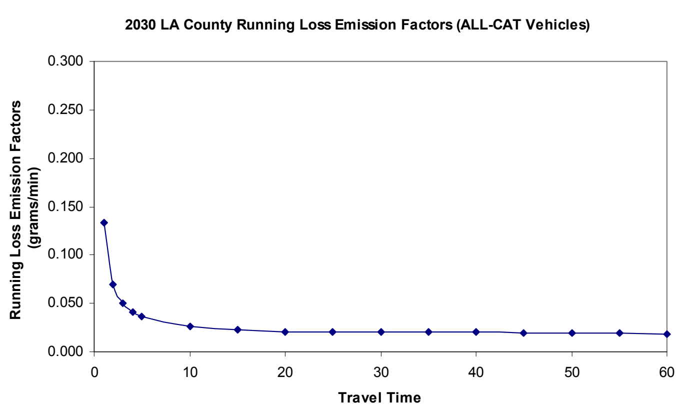
Running loss emissions:

*Emissions Inventory [grams] = (Emission rates [grams/minute]) * (Vehicle Time Traveled [minutes])*

Most transportation projects are assumed to ease congestion, thus reducing travel times. Shortened travel time periods result in lower running loss emissions. To calculate running loss TOG emissions, we use an emission factor based on EMFAC's running loss emissions calculated for a travel time of 60 minutes. Running loss emission factors are higher for shorter trips or travel time bins and lower for longer trips or travel time bins. Running loss emission factors, when plotted against travel time, tend to stabilize once travel times reach or exceed 20 minutes, as illustrated in Figure A-2. By employing an emission factor based on a 60-minute travel time bin, CT-EMFAC produces conservative estimates of the emission reduction benefits of congestion-relieving projects. Note that, by selecting the 60 minute bin for running loss emission factors, CT-EMFAC embeds an assumption that vehicles are warmed up. Such an assumption is appropriate for a project-level analysis since most vehicles have been operating long enough to be warmed up before getting on a freeway or major arterial.







Source: Bai et al., 2006 ("Estimating Mobile Source Air Toxics Emissions: A Step-By-Step Project Analysis Methodology," December 28, 2006).

Figure A-2. Illustration of change in running loss emission factors against travel time. Data shows are based on year 2004 Los Angeles County EMFAC runs. Emission factors stabilize by about the 10 minute mark for year 2004 (illustrated here), and by about the 20 minute mark for later analysis years such as 2013 or 2030.

APPENDIX B. CHOICE OF RELATIVE HUMIDITY AND TEMPERATURE

Emission factors generated from EMFAC2007 are not only by vehicle technology type and vehicle class but are also specific to combinations of temperature and relative humidity. The intervals of temperature and relative humidity are shown below.

```
Temperature Bins (F):         -20,-10,0,10,15,20,25,30,35,40,45,50,
                              55,60,65,70, 75,80,85,90,100,110,120

Relative Humidity Bins (%):   0,10,20,30,40,50,60,70,80,90,100
```

As shown above, there are 23 temperature bins and 11 relative humidity bins; this implies 253 (23 × 11) possible temperature and humidity combinations. Considering that the CT-EMFAC database had to include emission factors for 39 calendar years (i.e., 2002-2040) and 93 geographic areas (i.e., state, air basins, and counties), inclusion of all temperature and relative humidity combinations would have had a significant impact on data size. Inclusion of all combinations of analysis year, geographic area, temperature, and relative humidity were beyond the manageability of any database sized to be easily accessible by project analysts using desktop computer systems. Thus, as part of the model development process, we employed representative meteorological conditions to reduce the size of the emission factors database.

In CT-EMFAC, we chose to use a representative combination of temperature and relative humidity for each season and each geographic area. During the database development effort, we considered the fact that not all of the pollutant types are equally affected by temperature and relative humidity. A detailed look at the variation of emission factors over temperature and relative humidity (as shown in Figures B-1 through B-4) found that temperature and relative humidity do not affect PM emission factors; ROG emission factors vary slightly with temperature and do not change by relative humidity; NO_x emission factors are sensitive to both temperature and relative humidity; CO emission factors are sensitive to temperature but not to relative humidity within certain temperature ranges. We considered approaches that would select temperature and relative humidity values that would produce conservative (higher) emission factors. However, a pollutant-by-pollutant evaluation (see Figures B-1 through B-4) revealed that each pollutant was affected differently by meteorology. Thus, after consultation with both Caltrans and CARB, we determined that the most straightforward approach to developing the emission factor database was to select representative meteorological conditions for each geographic region, by summer and winter season and by annual average conditions. Table B-1 lists the representative meteorological conditions recommended by EMFAC2007.

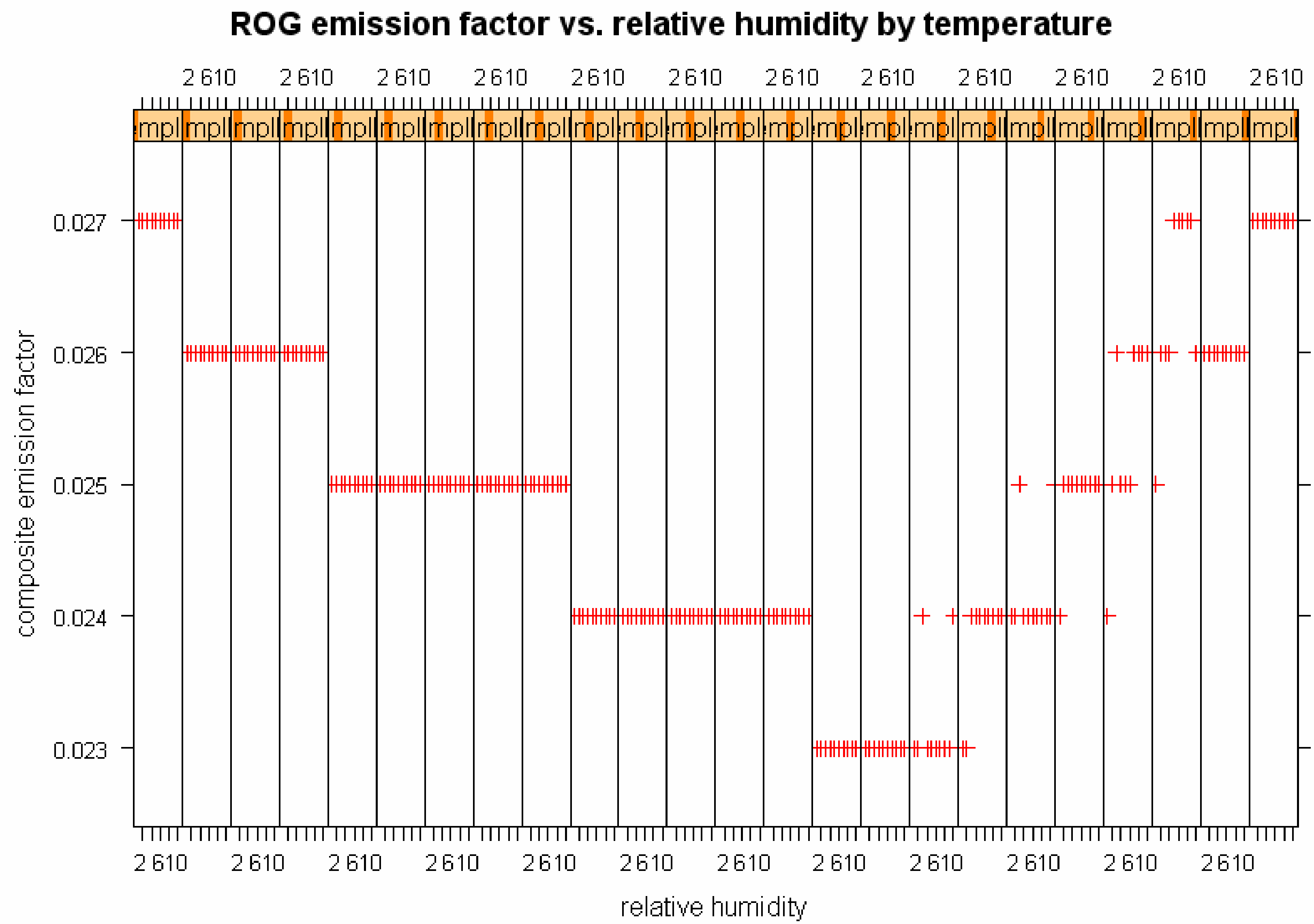
Table B-1. Representative Average Temperature and Relative Humidity.

area	Summer		Winter		Annual	
	Temp	RH	Temp	RH	Temp	RH
State	87	28	56	52	66	58
Great Basin Valleys	86	27	41	56	56	43
Lake County	91	21	47	72	62	57
Lake Tahoe	80	31	52	67	63	52
Mojave Desert	97	20	59	43	68	52
Mountain Counties	91	24	54	70	62	52
North Central Coast	85	28	51	75	60	70
North Coast	82	23	52	73	58	67
Northeast Plateau	83	25	43	77	53	56
Sacramento Valley	95	21	50	72	65	56
Salton Sea	100	17	62	36	73	46
San Diego	83	29	61	41	67	62
San Francisco Bay Area	89	23	52	71	62	63
San Joaquin Valley	95	21	49	72	67	55
South Central Coast	80	32	56	46	63	62
South Coast	84	34	60	37	68	55
Alameda	90	22	53	72	62	67
Alpine	80	33	46	70	51	48
Amador	93	23	56	68	64	52
Butte	93	23	52	72	65	55
Calaveras	93	23	57	73	65	54
Colusa	97	21	45	74	66	56
Contra Costa	91	21	50	73	63	60
Del Norte	75	29	47	79	48	77
El Dorado	91	24	53	65	63	51
El Dorado (LT)	80	31	53	65	63	51
El Dorado (MC)	89	25	53	65	63	51
Fresno	91	24	48	77	68	56
Glenn	95	22	48	71	66	56
Humboldt	78	26	54	75	56	76
Imperial	105	15	61	40	78	40
Inyo	93	22	45	56	59	43
Kern	97	20	51	60	67	52
Kern (SJV)	97	21	51	60	67	52
Kern (MD)	94	20	51	60	67	52
Kings	98	20	48	76	68	53
Lake	90	22	47	72	62	57
Lassen	82	24	40	75	53	50
Los Angeles	82	35	59	39	67	56
Los Angeles (SC)	96	20	59	39	67	56
Los Angeles (MD)	84	33	59	39	67	56
Madera	90	24	50	71	66	55
Marin	87	24	48	76	60	63
Mariposa	88	29	58	77	64	54
Mendocino	86	20	51	71	61	58

Table B-1. Representative Average Temperature and Relative Humidity, concluded.

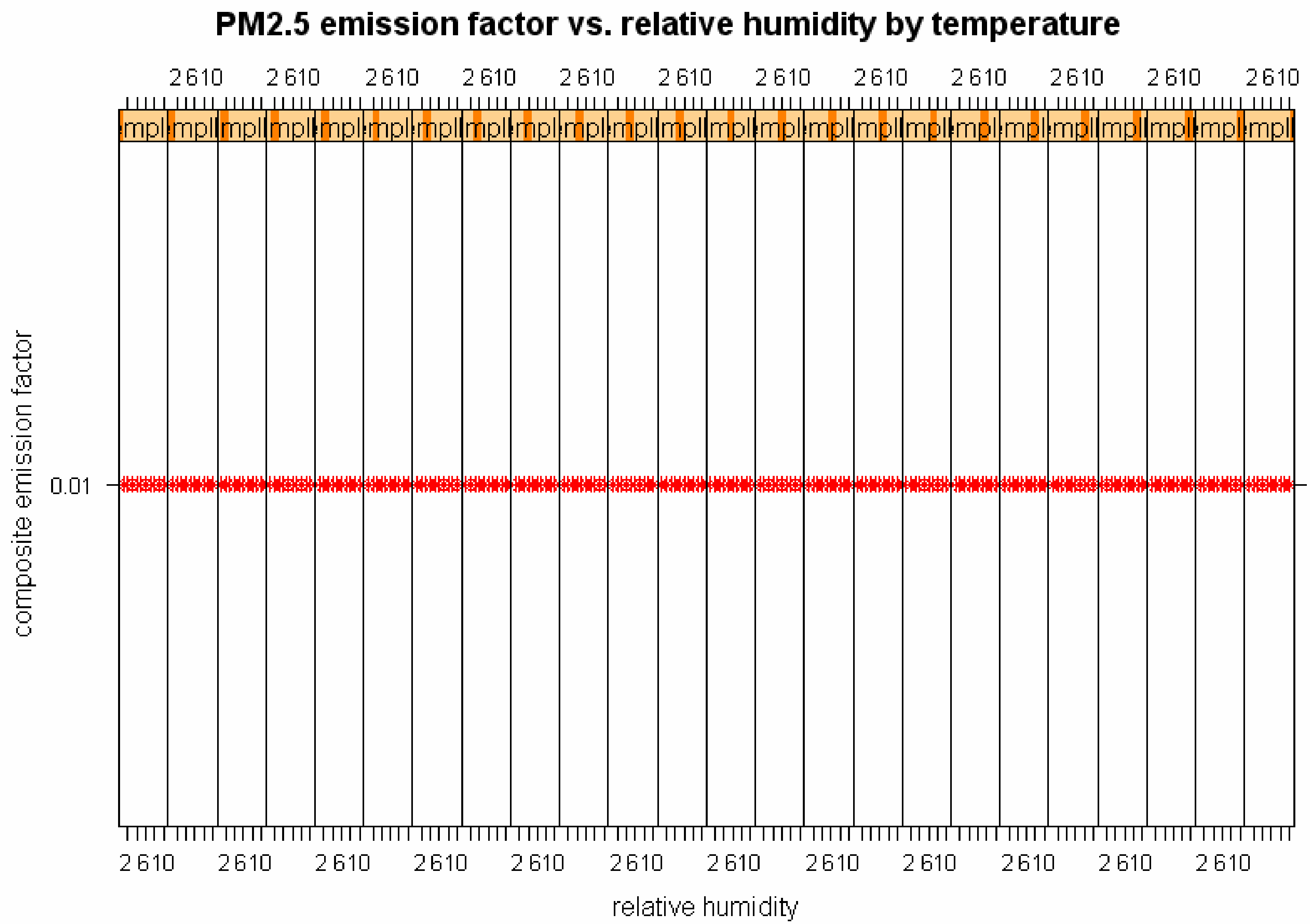
Merced	93	22	51	71	66	56
Modoc	82	25	40	79	52	56
Mono	81	31	35	55	52	41
Monterey	92	23	51	75	59	72
Napa	94	19	50	75	63	57
Nevada	89	25	53	71	62	52
Orange	83	34	61	33	68	59
Placer	95	21	51	71	64	54
Placer (LT)	80	30	51	71	64	54
Placer (MC)	85	27	51	71	64	54
Placer (SV)	97	21	51	71	64	54
Plumas	89	23	42	75	52	52
Riverside	93	24	62	35	70	49
Riverside (SC)	92	25	62	35	70	49
Riverside (SS)	103	16	62	35	70	49
Riverside (MDAQ)	107	14	62	35	70	49
Riverside (SCAQ)	98	18	62	35	70	49
Sacramento	95	21	50	73	65	56
San Benito	92	22	48	74	60	66
San Bernardino	93	23	60	40	68	50
San Bernardino (SC)	91	25	60	40	68	50
San Bernardino (MD)	101	17	60	40	68	50
San Diego	90	22	61	41	67	62
San Francisco	86	25	53	71	60	66
San Joaquin	93	22	48	75	65	59
San Luis Obispo	91	20	54	57	63	60
San Mateo	87	25	52	72	61	64
Santa Barbara	80	31	57	50	63	64
Santa Clara	88	24	53	67	64	62
Santa Cruz	87	27	53	74	60	68
Shasta	91	23	51	74	63	56
Sierra	87	25	45	71	54	51
Siskiyou	81	28	45	78	54	59
Solano	93	21	50	69	64	59
Solano (SV)	93	23	50	69	64	59
Solano (SF)	93	19	50	69	64	59
Sonoma	90	21	48	71	61	61
Sonoma (NC)	85	21	48	71	61	61
Sonoma (SF)	91	21	48	71	61	61
Stanislaus	93	22	50	75	66	59
Sutter	96	21	48	64	66	56
Tehama	93	22	51	74	66	56
Trinity	81	23	55	74	56	61
Tulare	91	24	49	76	67	53
Tuolumne	83	32	56	75	63	54
Ventura	84	28	56	40	64	62
Yolo	96	21	46	74	65	55
Yuba	94	22	52	65	65	54

Source: EMFAC2007.



-20	-10	0	5	10	15	20	25	30	35	40	45	50	50	55	60	65	70	80	85	90	100	110	120
Temperature																							

Figure B-1. Calendar year 2005 EMFAC2007 data illustrating ROG emission factor variability by temperature and relative humidity.



-20	-10	0	5	10	15	20	25	30	35	40	45	50	50	55	60	65	70	80	85	90	100	110	120
Temperature																							

Figure B-2. Calendar year 2005 EMFAC2007 data illustrating PM2.5 emission factor variability by temperature and relative humidity.

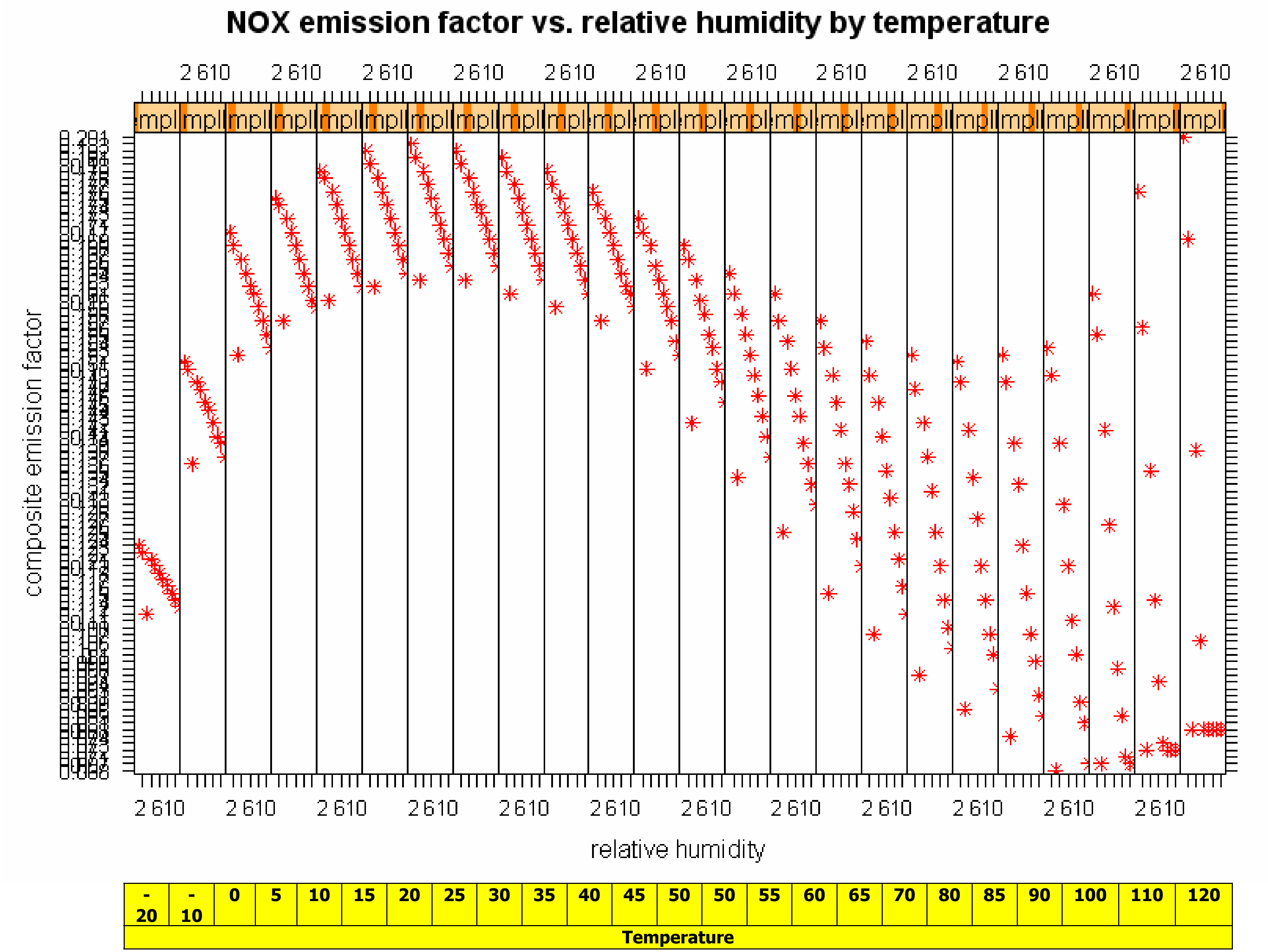
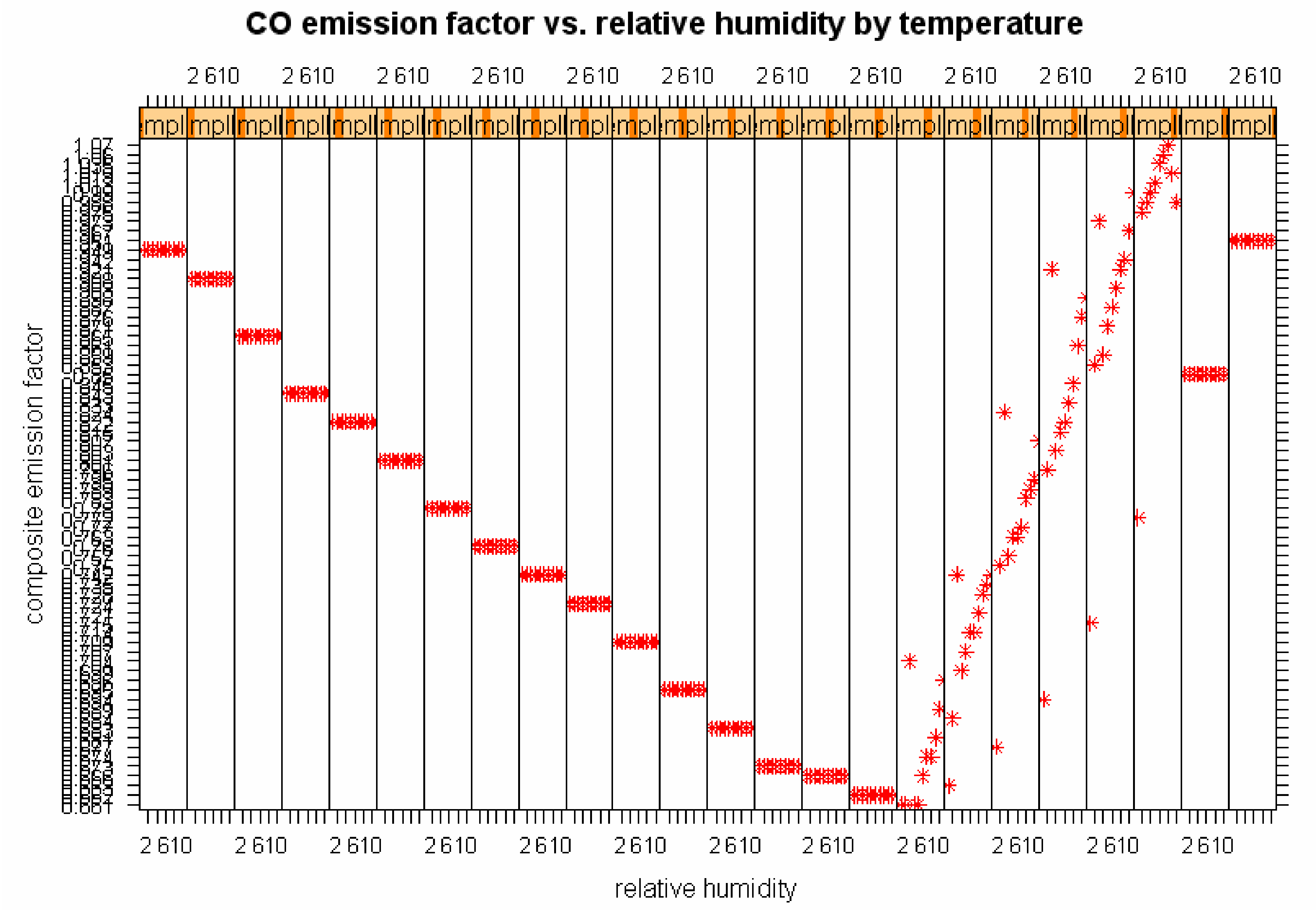


Figure B-3. Calendar year 2005EMFAC2007 data illustrating NOx emission factor variability by temperature and relative humidity.



-20	-10	0	5	10	15	20	25	30	35	40	45	50	50	55	60	65	70	80	85	90	100	110	120
Temperature																							

Figure B-4. Calendar year 2005 EMFAC2007 data illustrating CO emission factor variability by temperature and relative humidity.

APPENDIX C. QUALITY CHECK

This appendix includes a discussion of the quality control steps taken during CT-EMFAC's development. The development of CT-EMFAC was very data intensive, especially when assembling the database of intermediate composite emission factors. Vigorous quality control was essential during each step of the database and tool development process. Figure C-1 illustrates the flow of data manipulations and the points during tool development where quality control steps were implemented.

The first quality check performed was to ensure the integrity of the detailed emission factor data extracted from numerous EMFAC2007 "*.rtl" output files. An "*.rtl" file contains detailed emission factors by emission process and season as well as travel fractions by vehicle class and technology type for a specific calendar year and a geographic area. We generated files for 93 geographic areas and 38 calendar years. We wrote a program (in the programming language "R") to automatically extract the emission factors of interest from those 93 files, and to transform the data into a target database format. Once we extracted the emission factor data of interest, we quality checked the data to ensure that it had been properly generated and extracted. Table C-1 provides a summary of the quality assurance queries used to investigate the data included in the CT-EMFAC database. We compared the resulting database with the original *.rtl output files by checking example key information, such as year, season, emission factors by vehicle class and technology type and by emission process, temperature, and relative humidity.

The second quality check ensured the accuracy of developing intermediate composite emission factors. As discussed in the method section (see Appendix A), the process of calculating intermediate emission factors was computationally intensive, involving complex weighting processes based on various types of emission factors and travel fractions. The calculation of developing intermediate composite emission factors was done with a program written in the "R" programming language. The quality check was performed manually in EXCEL, following the same computing procedure as the R program.

Lastly, we checked whether the CT-EMFAC program correctly reported composite emission factors by comparing CT-EMFAC output with EMFAC2007 output. Tables C-2 and C-3 are example screen shots from the output files of this quality check. Tables C-2 and C-3 illustrate a quality check that compares EMFAC's output for CO against what CT-EMFAC produced, for the summer of 2011, statewide average, 87 degree temperature and 28% humidity.

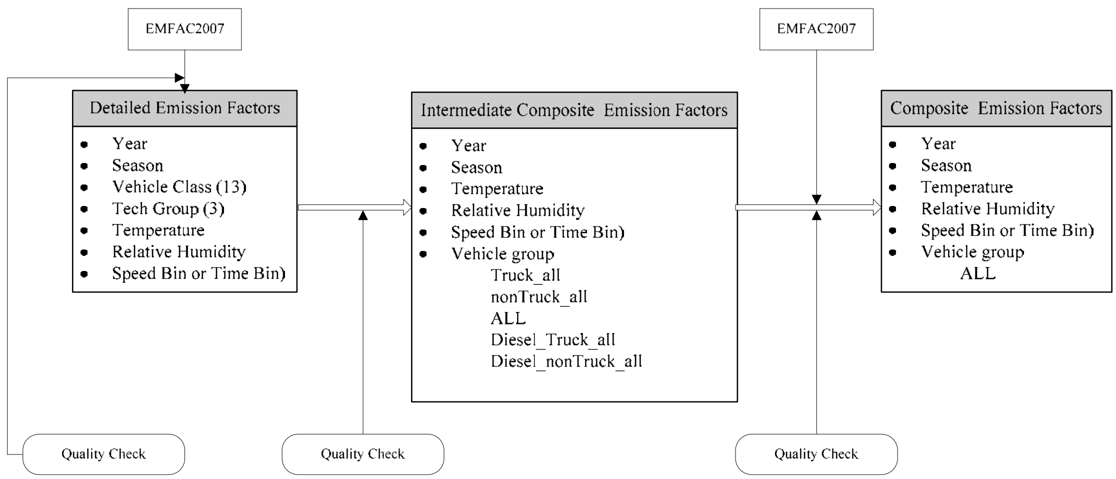


Figure C-1. Flow of Obtaining Composite Emission Factors and Quality Controls.

Table C-1. Q/A check list for CT-EMFAC database construction.

Selected areas	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8
Check which files? (*.in files)	State average	8_North_Coast Air Basin	50_Napa	58_Riverside	59_Riverside (SC)	60_Riverside (SS)	61_Riverside (MDAB)	62_Riverside (SCAB)
Number of scenarios = 9?								
Area method and area type correct?	State average	Air basic average	One county	County average	County subarea	County subarea	County subarea	County subarea
Area Number correct?								
PM modes complete?								
Calendar year complete? (2002 to 2040)								
Season correct?								
Relative Humidity correct?								
Temperature correct?								
Check which files? (*.rtl and *.csv files)	State average	8_North_Coast Air Basin	50_Napa	58_Riverside	59_Riverside (SC)	60_Riverside (SS)	61_Riverside (MDAB)	62_Riverside (SCAB)
Year/Season match?								
Temp/RH match?								
EMFAC emission match?								
VMT fractions match?								
Idling emission match?								
Index correct?								
Runningloss match?								

Table C-2. CT-EMFAC test output (compare to table C-3 results).

```
 Title           :    new-beta-test2
 Version         :    CT-EMFAC Beta 1.5
 Run Date        :    28 September 2007  10:05 AM
 Scen Year       :    2011
 Season          :    summer
 Temperature     :    87F
 Relative Humidity:    28%
 Area            :    state_average

====================================================================================================

          Running Exhaust Emissions (grams/mile)
----------------------------------------------------------------------------------------------------
         Pollutant Name   :  CO
   speed(mph)          Emission Factor
        5                  7.960000
       10                  6.530000
       15                  5.516000
       20                  4.793000
       25                  4.279000
       30                  3.888000
       35                  3.594000
       40                  3.383000
       45                  3.253000
       50                  3.207000
       55                  3.263000
       60                  3.457000
       65                  3.853000
       70                  4.306000
       75                  5.086000
----------------------------------------------------------------------------------------------------

          Idling Emissions (grams/idle-hour)
----------------------------------------------------------------------------------------------------

         Pollutant Name   :  CO
   speed(mph)          Emission Factor
        0                  5.382000
----------------------------------------------------------------------------------------------------

          Evaporative Running Loss Emissions (grams/minute)
----------------------------------------------------------------------------------------------------

-------------------------------------------------- END----------------------------------------------
```

Table C-3. EMFAC2007 output (compare to table C-2 results).

```
Title    : Statewide totals Avg Summer CYr 2011 Default Title
Version  : Emfac2007 V2.3 Nov 1 2006
Run Date : 2007/09/28 10:28:58
Scen Year: 2011 -- All model years in the range 1967 to 2011 selected
Season   : Summer
Area     : Statewide totals
*****************************************************************************************
Year:,2011,, -- Model Years,,1967, to ,2011, Inclusive --,,,Summer
     Emfac2007 Emission Factors: V2.3 Nov 1 2006

State Average,,,,,State Average,,,,,,State Average

,,,,Table  1:  Running Exhaust Emissions (grams/mile; grams/idle-hour)

Pollutant Name: Carbon Monoxide,,,,Temperature: 87F,,Relative Humidity: 28%

Speed, ..................................,   ALL,

    0, ..................................,  5.382,
    5, ..................................,  7.960,
   10, ..................................,  6.530,
   15, ..................................,  5.516,
   20, ..................................,  4.793,
   25, ..................................,  4.279,
   30, ..................................,  3.888,
   35, ..................................,  3.594,
   40, ..................................,  3.383,
   45, ..................................,  3.253,
   50, ..................................,  3.207,
   55, ..................................,  3.263,
   60, ..................................,  3.457,
   65, ..................................,  3.853,
```

APPENDIX D. MODEL VALIDATION AND COMPARISON

In this step, we compared the results from CT-EMFAC to those produced using a separate emissions modeling tool prepared by UC Davis under Caltrans sponsorship. The separate emissions modeling tool was a spreadsheet-based analysis tool designed to facilitate project-level MSAT assessment; it was developed in collaboration with Caltrans, the California Air Resources Board (CARB), and the U.S. Federal Highway Administration (see: Bai et al., 2006). Although the MSAT spreadsheet tool is not as sophisticated as CT-EMFAC, we were able to use the spreadsheet tool as a resource to identify inconsistencies in the output between CT-EMFAC and the spreadsheet. We were then able to investigate the source of the inconsistencies, and determine whether they were explained by the differing methodologies employed by the two tools, or whether they suggested potential model coding errors in either CT-EMFAC or the spreadsheet.

Since the spreadsheet tool was only able to estimate MSATs, this comparison focused on the six priority MSATs. Our quality assurance check employed data from a real-world freeway widening project in southern California, including travel activities for three calendar years and build versus no-build scenarios. To investigate the differences between the two tools we extracted estimates for no-build scenarios and peak traffic periods for three analysis years (2004, 2013, and 2030). The following discussion explains the differences observed between the emissions estimates produced by CT-EMFAC and the simplified spreadsheet tool. Table D-1 includes a summary of these emission differences. Table D-2 provides further detail on the differences between the two methods.

1. Diesel PM Differences

The spreadsheet tool estimates diesel PM emissions from medium duty and above diesel-powered vehicles; light duty diesel vehicles are excluded from the analysis. However, CT-EMFAC calculates diesel emissions for the whole fleet. The importance of this difference in the methodologies grows over time. EMFAC2007 embeds assumptions that diesel PM emission factors from trucks will decrease substantially in future years due to fleet turnover and more stringent truck emission standards. However, EMFAC2007 assumes that diesel PM emission factors for nontrucks decrease more slowly over time, compared to the rate at which truck emissions decline. Therefore, nontruck diesel PM emissions grow as a fraction of overall diesel PM emissions in future years. The lack of any inclusion of light-duty diesel PM in the spreadsheet tool therefore adds to the discrepancy between the two methods in later analysis years (see Table D-1). For example, note how EMFAC2007 diesel PM emission factors change over time (the example below is EMFAC2007 g/mi emission factor output for 30 mph):

Year, Light-Duty Class	(Emission Factor);	Truck Class (Factors)
2004, LDA & LDT1 & LDT2	(0.156, 0.061, 0.104);	MHD & HHD (0.313, 0.933)
2013, LDA & LDT1 & LDT2	(0.122, 0.051, 0.074);	MHD & HHD (0.206, 0.377)
2030, LDA & LDT1 & LDT2	(0.041, 0.038, 0.043);	MHD & HHD (0.119, 0.085)

Note, for example (as illustrated above), that from 2004 to 2030, heavy-heavy-duty diesel PM emission factors decline over 90%, while light-duty truck 2 factors decline less than 60%.

In addition to the differences involving light-duty diesel PM, CT-EMFAC and the spreadsheet tool differ in their handling of diesel-powered buses and motor homes. The spreadsheet tool does not include an accounting of the vehicle miles traveled (VMT) by buses and motor homes, thus missing an important contributor to diesel PM emissions. Finally, the two methods composite truck emissions differently (see the discussion below under gaseous MSAT differences). Together, these differences explain why the two methodologies result in different diesel PM emission estimates.

2. Gaseous MSAT differences

First, as one check on CT-EMFAC's output, we reproduced, using Excel, the calculations CT-EMFAC employs to estimate MSAT emissions. [Note that this Excel exercise did not involve the MSAT spreadsheet tool developed in collaboration with Caltrans, CARB, and FHWA; it employed a one-time Excel-based analysis constructed to duplicate CT-EMFAC's algorithms as a quality check for the model.] These analyses were completed for a 2030 no-build scenario using real-world activity data from a southern California freeway widening project. The Excel exercise generated results that duplicated the CT-EMFAC output, except for minor rounding differences.

Second, we checked how the different speciation factors used by CT-EMFAC and the spreadsheet tool (the tool developed in collaboration with Caltrans, CARB, and FHWA) would contribute to observed output differences. The spreadsheet tool simplified the MSAT calculation process by applying only selected speciation factors. The spreadsheet tool used LDT1 MSAT speciation factors, and applied those to all 13 vehicle classes represented in EMFAC2007. At the time of the spreadsheet tool's preparation, this simplification was used to limit the computational complexity involved in generating emission factors, and to generally err on the side of producing higher MSAT emissions. Note that, in contrast to the spreadsheet tool, CT-EMFAC applies separate speciation factors across all 13 EMFAC vehicle classes. In comparison to CT-EMFAC, the spreadsheet tool could either underestimate or overestimate emissions depending on which calendar year is modeled. For the most recent years (e.g., 2004), the spreadsheet tool tends to be conservative because the speciation factors of the LDT1 vehicle class are higher compared to the other vehicle classes. This is not always the case in future analysis years (e.g., 2030), and it also varies by individual MSATs. For example, for benzene, butadiene and acrolein, the spreadsheet tool conservatively selects speciation factors for non-diesel vehicles (for year 2004, it applies LDT1 speciation factors to all nondiesel vehicles); the result is that CT-EMFAC provides lower estimates than the spreadsheet tool. However, for year 2030, LDT1 speciation factors are not always the highest among the vehicle classes (for example, motorcycles and medium-duty vehicles have a higher TOG speciation fraction for aldehydes and benzene than do LDT1 vehicles). Thus, in some instances, CT-EMFAC year 2030 MSAT estimates can be higher than those produced by the spreadsheet tool.

To test how the choice of speciation factors would affect the results, we used the speciation factors incorporated in the spreadsheet tool, but calculated MSAT emissions by following CT-EMFAC's procedure in Excel. This quality check allowed us to isolate the impact of speciation factor choice in explaining the differences between the two methods. For example, in 2030, the spreadsheet tool applies acetaldehyde speciation factors for medium duty trucks that are much smaller than those included in EMFAC2007 and CT-EMFAC. Considering the relatively large VMT fraction coming from medium duty trucks (10%), the spreadsheet tool significantly underestimates acetaldehyde emissions compared to CT-EMFAC. Therefore, the different ways of choosing speciation factors largely contributed to the observed difference in results between CT-EMFAC and the spreadsheet tool.

The remaining difference in the aldehyde emissions was determined to be due to the different methods of calculating composite emissions factors. The spreadsheet tool calculates composite emission factors by compositing diesel and nondiesel vehicles; CT-EMFAC however, composites emission factors from trucks and nontrucks. Also, as described in the diesel PM discussion, the spreadsheet tool treats all diesel vehicles in the nontruck classes as non-diesel vehicles, thus ignoring their contribution during the compositing process. These mathematical artifacts caused the remainder of the differences observed between CT-EMFAC and the spreadsheet tool.

For both benzene and acrolein, the differences between the two approaches were entirely a function of the fact that the spreadsheet tool employs simplified, more conservative speciation factors in the early analysis years. The LDT1 speciation factors used by the spreadsheet tool are higher in the early analysis years, but are less conservative in later analysis years. Thus, the benzene and acrolein discrepancies illustrated in Table D-1 became smaller over time.

3. Reference

Bai S., Eisinger D., and Niemeier D. (2006) Estimating mobile source air toxics emissions: a step-by-step project analysis methodology. Report prepared for the California Department of Transportation, Sacramento, CA, by the University of California, Davis-Caltrans Air Quality Project, Davis, CA, October.

Table D-1. MSAT results from CT-EMFAC compared with results from a simplified MSAT estimation spreadsheet tool.

	Scenarios		
	2004 no-build Peak	2013 no-build Peak	2030 no-build Peak
Spreadsheet Tool			
Diesel PM	5911	5669	2513
Benzene	4699	2610	1074
Butadiene	908	453	147
Acetaldehyde	1378	1199	611
Acrolein	206	100	32
Formaldehyde	4153	3109	1467
CT-EMFAC			
Diesel PM	6550	6389	2959
Benzene	4221.776	2389.439	1070.674958
Butadiene	796.106	403.2606	156.436629
Acetaldehyde	1319.169	1254.969	678.72674
Acrolein	181.1036	88.32024	32.9479
Formaldehyde	3902.389	3141.188	1596.655234
Percentage Difference			
Diesel PM	10.81%	12.70%	17.75%
Benzene	-10.16%	-8.45%	-0.31%
Butadiene	-12.32%	-10.98%	6.42%
Acetaldehyde	-4.27%	4.67%	11.08%
Acrolein	-12.09%	-11.68%	2.96%
Formaldehyde	-6.03%	1.04%	8.84%

Units: grams. Results were generated based on travel activity assumptions related to a real-world freeway widening project. See Table D-2 for further detail.

Table D-2. Complete outputs of CT-EMFAC and MSATs spreadsheet tool.

Scenario Run #	**1**		**2**		**3**		**4**		**5**	
Scenario Title	Base year no-build		Operational year no-build		Operational year build		Horizon year no-build		Horizon year build	
Geographic Area	County: Los Angeles		County: Los Angeles		County: Los Angeles		County: Los Angeles		County: Los Angeles	
Analysis Year	2004		2013		2013		2030		2030	
Season	Annual		Annual		Annual		Annual		Annual	
Vehicle Mix	Peak (off-peak)		Peak (off-peak)		Peak (off-peak)		Peak (off-peak)		Peak (off-peak)	
Truck %	9.39% (9.39%)		9.9% (15.9%)		9.4% (15.8%)		12.7% (19.5%)		11.1% (18.0%)	
Others %	90.61% (90.61%)		90.1% (84.1%)		90.6% (84.2%)		87.3% (80.5%)		88.9% (82.0%)	
Pollutants	DPM, 5 MSATs		DPM, 5 MSATs		DPM, 5 MSATs		DPM, 5 MSATs		DPM, 5 MSATs	
Toxics Speciation	CARB Factors		CARB Factors		CARB Factors		CARB Factors		CARB Factors	
Emission Factors	Current		Current		Current		Current		Current	
Travel activities										
Speed: pk (off-P)	36 (61)		32 (65)		58 (65)		25 (41)		40 (55)	
VMT: pk (off-P)	524938 (709523)		684653 (845835)		962723 (1004357)		658958 (849701)		1010420 (1084241)	
Pollutants	DPM, 5 MSATs		DPM, 5 MSATs		DPM, 5 MSATs		DPM, 5 MSATs		DPM, 5 MSATs	
CT-EMFAC results	Peak	off-peak	Peak	off-peak	Peak	off-peak	Peak	off-peak	Peak	off-peak
DPM	6550	8714	6389	15634	9494	18456	2959	4617	3471	6412
Benzene	4222	5400	2389	2924	2748	3469	1071	1002	1114	1256
Butadiene	796	1092	403	549	518	652	156	148	172	214
Acetaldehyde	1319	1816	1255	2097	1411	2478	679	833	644	826
Acrolein	181	248	88	118	115	140	33	30	37	46
Formaldehyde	3902	5353	3141	5017	3624	5934	1597	1880	1549	1970
Spreadsheet results	Peak	off-peak	Peak	off-peak	Peak	off-peak	Peak	off-peak	Peak	off-peak
DPM	5911	8065	5669	14720	8475	17324	2513	4342	2921	6041
Benzene	4699	5876	2610	3090	2971	3666	1074	978	1095	1180
Butadiene	908	1205	453	582	559	691	147	137	156	186
Acetaldehyde	1378	1862	1199	2023	1325	2386	611	777	556	737
Acrolein	206	274	100	126	125	150	32	28	34	41
Formaldehyde	4153	5580	3109	4942	3535	5835	1467	1773	1378	1788

Units: grams. Results were generated based on travel activity assumptions related to a real-world freeway widening project.